

Divergence in Architectural Research

Proceeding Book of
ConCave Ph.D. Symposium
Georgia Institute of Technology
Atlanta, Georgia
March 5-6, 2020.

Edited by
Hayri Dortdivanlioglu
Marisabel Marratt

School of Architecture Publication



Divergence in Architectural Research

Edited by
Hayri Dortdivanlioglu
Marisabel Marratt

February 2021

Divergence in Architectural Research

Editors

Hayri Dortdivanlioglu, Marisabel Marratt

Copy Editors

Gillian Gingher, Marisabel Marratt, Hayri Dortdivanlioglu

Graphic Designer

Hayri Dortdivanlioglu

Printer

RR Donnelley
Atlanta, GA

© Copyright 2021

Georgia Institute of Technology
School of Architecture
247 4th Street NW
Atlanta, Georgia 30332-0155

All rights reserved by individual project authors who are solely responsible for their content.

No part of this work covered by copyright may be reproduced or used in any form, or by any means graphic, electronic or mechanical, including recording, taping or information storage and retrieval systems without prior permission from the copyright owner.

ISBN 978-0-9615650-1-5

CONCAVE Ph.D. Symposium:
DIVERGENCE
IN ARCHITECTURAL
RESEARCH

March 5-6, 2020
Atlanta, Georgia

CONCAVE
Ph.D. Student Group in Design

Georgia
Tech 
College of Design
School of Architecture
Student Foundation

Acknowledgements

In the late spring of 2019, the ConCave Ph.D. Student Group in Design of the School of Architecture at Georgia Tech began plans for what would become, almost a year later, in March 2020, the symposium "Divergence in Architectural Research." From the outset, the symposium team envisioned the creation of a blueprint for what would be, it is hoped, the first of many future symposia. The goal was simple but the task was daunting.

The symposium and this book would not have seen the light of day without the generous support of the School of Architecture, the College of Design, and the Student Foundation at the Georgia Institute of Technology. Very special thanks are owed to Dean Steven French, Associate Dean for Research Nancey Green Leigh, and Chair Scott Marble for seeing the merit of the proposal and for challenging us at every step to properly see it through. Thanks are also due to the Board of the Georgia Tech Student Foundation for extending our window for accessing funds, as we encountered the inevitable Covid-19 delays in this book's planning and publication. With the funding provided by these, ConCave was able to envision and organize, from the outset, an event, and publication of true international reach, capable of showcasing the breadth of architectural research taking place in doctoral programs worldwide.

The symposium also owes a great debt of gratitude to Assistant Professor Tarek Rakha, for his invaluable guidance as faculty advisor, and to faculty members at Georgia Tech and at other institutions internationally, who as members of the scientific committee, generously gave of their time and expertise during the peer review process. We specifically wish to thank Professor Stephen Phillips of California Polytechnic State University and Associate Professor Kathy Velikov of University of Michigan for enlightening us with their keynote speeches and workshops. We thank Professor George Johnston, Professor Athanassios Economou, Associate Professor Perry Yang, Associate Professor Nassim Parvin of the Ivan Allen College of Liberal Arts, Associate Professor Todd Cronan of Emory University, Associate Professor Joseph Choma of Clemson University, Assistant Professor Lydia Kallipoliti of The Cooper Union, Assistant Professor Tarek Rakha, and Assistant Professor Danielle Willkens for their invaluable assistance as moderators to our panel discussions. We also thank Professor Ellen Dunham-Jones, Professor Lars Spuybroek, Professor George Johnston and Associate Professor Perry Yang for joining us and presenting their new books. The successful planning and execution of the event would not have been possible without the ever professional and cheerful assistance of the staff in the School of Architecture administration, specifically Carmen New, Isra Hassan, Jennifer Burton, and Robin Tucker.

Finally, our greatest thanks go to the participants of the symposium and the authors presented in this book. This book is only possible thanks to their generous presence and contributions during the event and afterwards, as well as their kind encouragement, responsiveness, and patience, during the process of refining and editing of the final result.

Organizing Committee:

Hayri Dortdivanlioglu
Academic Coordinator
Ph.D. Student, Georgia Institute of Technology

Yousef Bushehri
Exhibition Coordinator
Ph.D. Student, Georgia Institute of Technology

Marisabel Marratt
Academic Coordinator
Ph.D. Student, Georgia Institute of Technology

Zorana Matic-Isautier
Hospitality Coordinator
Ph.D. Student, Georgia Institute of Technology

Tarek Rakha
Academic Advisor
Assistant Professor, Georgia Institute of Technology

Sevda Babalou
Public Relations
Ph.D. Student, Georgia Institute of Technology

Advisory Board:

Steven French, *Dean and John Portman Chair, College of Design*
Nancey Green Leigh, *Associate Dean for Research, College of Design*
Scott Marble, *William H. Harrison Chair, School of Architecture*

Scientific Committee:

Anjali Joseph, *Endowed Chair, Clemson University, USA*
Arash Soleimani, *Assistant Professor, Kennesaw State University, USA*
Arief Setiawan, *Assistant Professor, Kennesaw State University, USA*
Azadeh Sawyer, *Assistant Professor, Carnegie Mellon University, USA*
Benay Gursoy Toykoc, *Assistant Professor, Penn State University, USA*
Christina Crawford, *Assistant Professor, Emory University, USA*
Clio Andris, *Assistant Professor, Georgia Institute of Technology, USA*
Craig Zimring, *Professor, Georgia Institute of Technology, USA*
Danielle Wilkens, *Assistant Professor, Georgia Institute of Technology, USA*
Dennis Shelden, *Associate Professor, Georgia Institute of Technology, USA*
Dimitris Papanikolaou, *Assistant Professor, University of North Carolina, USA*
Elisa Dainese, *Assistant Professor, Dalhousie University, Canada*
Ellen Dunham Jones, *Professor, Georgia Institute of Technology, USA*
Eyal Weizman, *Professor, Goldsmiths, University of London, UK*
Gabriel Wurzer, *Researcher, Vienna University of Technology, USA*
George Johnston, *Professor, Georgia Institute of Technology, USA*
Ingrid Rowland, *Professor, University of Notre Dame, USA*
Ipek Tureli, *Associate Professor, McGill University, Canada*
Jean-Hugues Barthélémy, *Professor, l'Université Paris-Nanterre, France*
Jeffrey Collins, *Assistant Professor, Kennesaw State University, USA*
Jihan Sherman, *Academic Professional, Georgia Institute of Technology, USA*
John Haymaker, *Director of Research, Perkins+Will, USA*
Kereshmeh Afsari, *Assistant Professor, Virginia Tech, USA*
Lars Spuybroek, *Professor, Georgia Institute of Technology, USA*
Lisa Lim, *Assistant Professor, Texas Tech University, USA*
Lydia Kallipoliti, *Assistant Professor, The Cooper Union, USA*
Mine Ozkar, *Professor, Istanbul Technical University, Turkey*
Moa Carlsson, *Lecturer, University of Edinburgh, UK*
Momen El-Husseiny, *Assistant Professor, The American University in Cairo, Egypt*
Pavlos Lefas, *Professor, University of Patras, Greece*
Perry Yang, *Associate Professor, Georgia Institute of Technology, USA*
Reinhard Koenig, *Junior-Professor, Bauhaus-University Weimar, Germany*
Robert Rosenberger, *Associate Professor, Georgia Institute of Technology, USA*
Roya Rezaee, *Research Scientist, Perkins+Will, USA*
Ryan Roark, *Ventulett Next Generation Fellow, Georgia Institute of Technology, USA*
Saif Haq, *Professor, Texas Tech University, USA*
Seray Turkey, *Assistant Professor, TED University, Turkey*
Siobhan Rockcastle, *Assistant Professor, University of Oregon, USA*
Sonit Bafna, *Associate Professor, Georgia Institute of Technology, USA*
Tarek Rakha, *Assistant Professor, Georgia Institute of Technology, USA*
Athanasios Economou, *Professor, Georgia Institute of Technology, USA*
Thomas Grasl, *SWAP Architects, Germany*
Todd Cronan, *Associate Professor, Emory University, USA*
Vernelle A. Noel, *Ventulett Next Generation Fellow, Georgia Institute of Technology, USA*
Zachary Tate Porter, *Assistant Professor, University of Nebraska-Lincoln, USA*
Zenovia Toloudi, *Assistant Professor, Dartmouth College, USA*

The essays in this volume have come together under the theme “Divergence in Architectural Research” and present a snapshot of Ph.D. research being conducted in over thirty architectural research institutions, representing fourteen countries around the world. These essays also provide a window into the presentations and discussions that took place March 5-6, 2020, during the ConCave Ph.D. Symposium “Divergence in Architectural Research,” under the auspices of the School of Architecture, Georgia Institute of Technology, in Atlanta, Georgia.

On a preliminary reading, the essays respond to the call of divergence by doing just that; they present the great diversity of research topics, methodologies, and practices currently found under the umbrella of “architectural research.” They inform inquiry within architectural programs and across disciplinary concentrations, and also point to the ways that the academy, research methodologies, and the design profession are evolving and encroaching upon one another, with the unspoken hope of encouraging new relationships, reconfiguring previous assumptions about the discipline, and interweaving research and practice.

The research that follows does not seek to define divergence; in fact, it is easier to say what it is not than what it is. For example, divergence is not synonymous with inter-disciplinarity, which emphasizes a sharing across established boundaries. Inter-disciplinarity seeks resemblances and shared methods and motivations, ignoring all the rest. The search for sameness usually remains on the surface; it is unsustainable over a long-term and ultimately not very effective for investigating the breadth and depth of a discipline. Rather, from within architecture, the projects that follow choose to explore subjects, techniques, and methodologies that diverge, sometimes intentionally, sometimes organically, from the canon of research in architecture. In doing so, they expand the field of exploration and also point to how this canon, once privileged as a means of ordering and defining a distinct cultural and professional identity, may also have inadvertently reduced the subject’s active, living quality—architecture’s agency. These essays take architecture’s agency as primordial, with its variations, energies, and movements, and allow it to shape the course of their research program, their conclusions, and their speculations for the future of research in architecture.

Given its shape-shifting qualities, it is not possible to define divergence, yet it is fruitful to map its movement throughout these essays. The mapping reveals that divergence describes multiple strategies for defining the subject matter, developing methodologies, collecting and analyzing the evidence, and structuring research agendas. These strategies operate across the typical research concentrations found in academic programs. Thus, following the trace of Divergence as Transformation and Mutation, research projects focused in history and theory, evidence-based design, and urbanism and social justice follow the evolution of existing socio-economic and technological conditions to generate new subject matter and refine existing methodologies. Divergence as Interpretative Action informs diverse research projects that seek to re-interpret existing evidence, using new heuristic models and sources (at times borrowed from other disciplines), to confront institutionalized agendas and interpretations. In this scenario, divergence presents a moment of difference that has the potential to highlight forgotten perspectives, invisible populations, and ill-considered or negated evidence. Divergence as Epistemological Strategy refers to those projects that choose to investigate new analytic frameworks, material systems, and research methodologies in order to improve capture of cognitive processes and evidence and foster an environment of inclusion for marginalized agents, techniques, and design and construction conditions. Divergence as Expansion of Possibility moves away from a closed system of abstract norms to allow space for variation, and the inclusion of those formless potentials and ineffable interactions that expand the evidence base and provide greater resolution to our mappings of patterns of emergence in architectural phenomena. Divergence

as Destabilizing Gap seeks to investigate the outlines of epistemological frameworks and assumes an always-existing but often-observed gap between actual conditions and our methods of capture; awareness of the gap destabilizes current knowledge frameworks and habits of observation and, in doing so, paradoxically presents the possibility of continuity, even as it disrupts. Finally, Divergence as Reframing of Perception will describe projects that seek to shift our perception of the subject matter, either by developing new research methods, reframing our conceptual approach, or questioning assumptions relative to research and the profession as a whole.

None of these strategies is mutually exclusive; the distinctions are subtle and, in many instances, they overlap or represent different phases in the development of research projects. Certain variants of the strategies may also be better adapted to specific concentrations or research topics. It may be argued that, in order to define and launch any research topic, a spirit of divergence is required; how else to argue for a research contribution as pertinent and necessary for the expansion of the field? However, in following these various facets of a divergence theme, we hope to highlight and celebrate just how far current architectural research is expanding beyond the constraints of the established disciplinary canon.

From the outset, the theme of divergence has presented the symposium and this book with a paradox. Calling for a convergence of research voices focused on a particular theme, as follows the framework of a classical symposium, the theme itself inverts this initial idea of confluence by highlighting a state of fertile chaos, as expressed in the diversity of concentrations, topics, methods, and practices, each proposing in their own fashion, to touch a core that is inefably architectural. Forty-odd participants traveled to Atlanta from all points of the globe in that first week of March and rose to this challenge. They brought with them their research, their modes of observing, questioning, implementing, and the varied experiences that served to influence their path and allow this research to flourish.

The essays were initially proposed and the symposium structured, according to the typical research agenda within academia, which follows the contours of defined concentrations. Yet, as is often the case, these concentrations-as-categories, while handy for initially structuring the material, soon revealed their inadequacy. They became, instead, reductive fictions that shut down the conditions of possibility our divergent approach sought to foster. The limitations of these concentrations became all the more apparent as they sought to encapsulate a subtle spectrum of research practices, spanning the history and theory of architecture and urbanism, social justice in architecture, media technologies, epistemologies, and the historiography of representation, aesthetics, space and politics, building and envelope performance, design methodologies, data structures and computation, and new materials and construction technologies. The categories established by these concentrations simply did not suffice, and further, functioning as categories are wont to, suppressed what was specifically divergent, in order to find “a fit” under a particular identity.

Structuring and designing this book allowed us to test the mechanics of divergence further. During the event itself, a little experimentation took place, as we formed panels of shared interests, but with a mix of styles and methodologies provoking a more far-reaching discussion, grounded in some notion of architectural research and practice. In that context, it became evident that these tactics could be played an infinite number of ways, limited only by the constraints imposed by the event’s time and space. The formatting of this book presents a different opportunity to free us from the strict constraint of a linear time-space sequence, provided we take certain liberties in how we peruse the actual contents within. We wish to suggest that these essays could be put in relation any number of ways; each pattern of relations proposes a mapping for entering into the material, and each map suggests a different path for further approaching and expanding the terrain of architectural discourse.

We have elected not to structure the physical book according to categorical sections, which would always leave us wanting and risk neutralizing the richness of the individual projects. We choose to present the divergent mobility of the material in quasi-encyclopedic fashion by organizing the essays alphabetically, according to author. To this end, the diagrams that are presented in the beginning of the book offer diverse options for structuring and entering into the research that follows, all the while knowing that there are potentially infinite ways to map these topics and define research paths. We encourage each reader to design their own map, according to their own research interests and agendas.

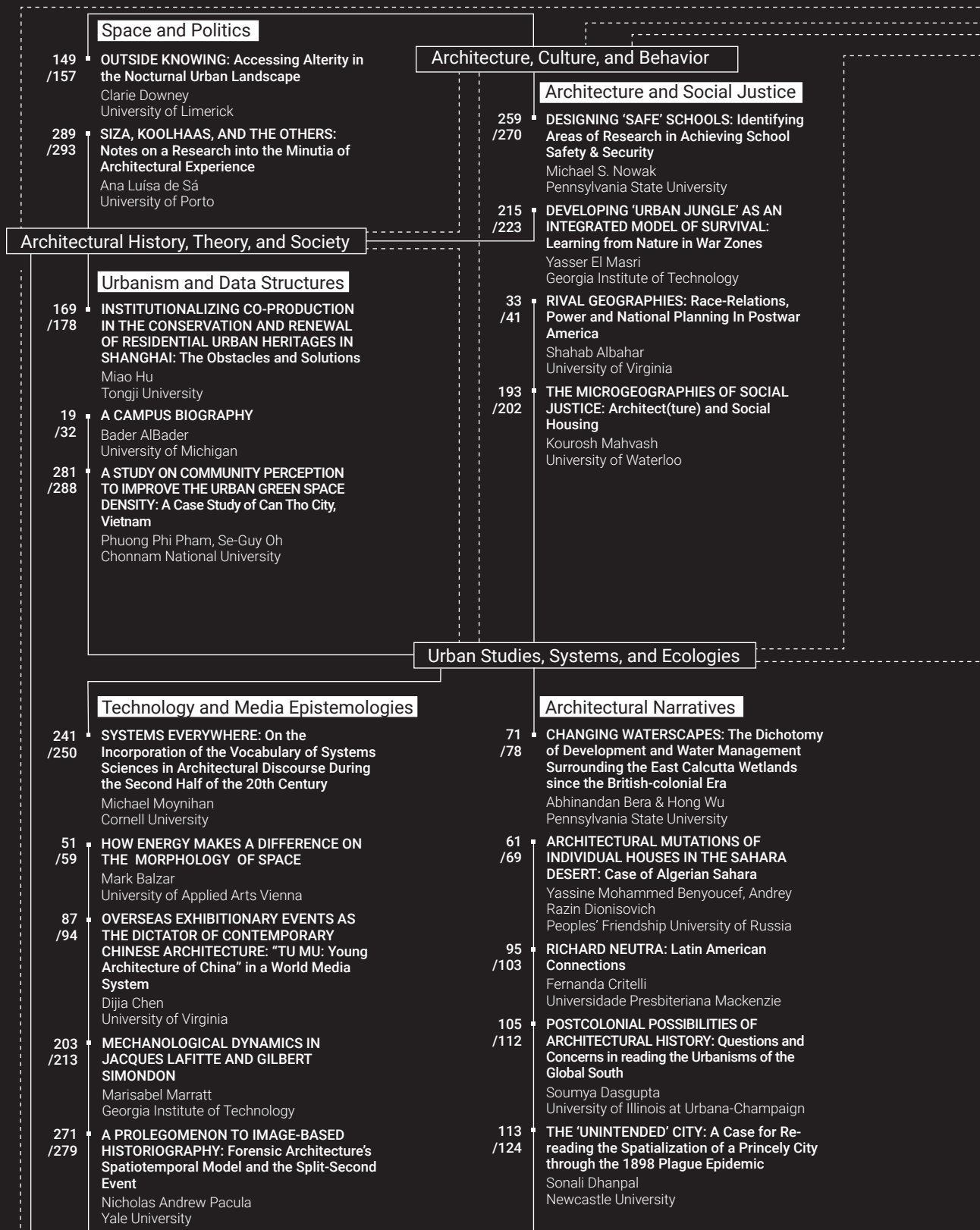
It seems like quite a neat rhetorical flip to say that a call for research, along the lines of divergence, should have elicited such a convergence of research offerings. From the initial call, over one hundred submissions were received, which after two-tier double-blind peer review, resulted in the group of essays enclosed within this volume. The desire to be included and yet remain divergent is a complex contradiction, which certainly lent palpable energy to the events of the symposium. Yet it is possibly in the aftermath of the symposium that this divergent energy and these research projects manifest their true character as powerful devices generative of future discourses. Not a week had passed after the symposium that the Covid-19 novel virus was declared a global pandemic; in the space of a day, the entire world was immobilized in a state of quarantine. In our brave new existence as disembodied heads populating a virtual patchwork of faces, the symposium and the in situ, pluri-voiced discussions that took place in the flesh seemed almost more powerful than our reality; they now entered our experience like fertile phantasms, every now and then emerging, disrupting and momentarily fusing our multiple-yet-solitary, diverging worlds.

The initial thought was that divergence would allow us to encompass and define a more expansive, more inclusive, and more generative means for addressing and building future research agendas within the Architecture doctoral pedagogy, but perhaps it is in this new, motile, subterranean confluence of voices where its real power lies.

Atlanta, 2021







Design Technologies, Data, and Performance

Design Methodologies and Computation

- 79 /86 ■ **GRAPHS, SETS AND COVERS; SEEING WHAT HAS ALWAYS BEEN THERE: Finding Common Ground between BIM Applications and Their Users**
Mehmet Sinan Bermek
Georgia Institute of Technology
- 251 /258 ■ **AGENT BASED SEMIOLOGY: Simulating Contemporary Office Occupation Patterns with Simplified Social Models**
Robert R. Neumayr
University of Applied Arts Vienna
- 295 /305 ■ **MACHINE LEARNING FOR ARCHITECTS AND DESIGNERS: Implementing Machine Learning into the Digital Design Process**
Adam Sebestyen
Vienna University of Technology, New Design University St. Pölten

Building Skin and its Performance

- 179 /186 ■ **THE FEASIBILITY OF NATURAL VENTILATION IN CHICAGO'S TALL OFFICE BUILDINGS USING DOUBLE-SKIN FAÇADES**
Yohan Kim
Illinois Institute of Technology
- 233 /239 ■ **PERFORMANCE-BASED FACADE DESIGN TOOL: Approach for Automated and Multi-Objective Simulation and Optimization**
Mahsa Minaei
University of Massachusetts Amherst
- 355 /364 ■ **FROM SEGREGATED TO INTEGRATED: The Evolution of Shading Designs in Marcel Breuer's Works**
Yuan Yao
Southeast University
- 317 /324 ■ **OPERABLE WINDOWS, THERMAL COMFORT, AND INDOOR AIR QUALITY IN K-12 SCHOOLS: Identifying the Gap and Proposing Future Studies**
Helia Taheri, Traci Rose Rider
North Carolina State University
- 347 /354 ■ **SHAPE-CHANGING ARCHITECTURAL SYSTEMS: A Bottom-up and Top-down Approach for Developing Responsive Building Skins**
Elena Vazquez
Pennsylvania State University

Design Methods, Computing, and Production

Historiography of Representation and Design

- 187 /191 ■ **A CRITICAL INQUIRY INTO THE 'PROBLEM' OF STOPPING IN ARCHITECTURE**
Skender Luarasi
POLIS University
- 137 /147 ■ **WEAVING FABRICA AND RATIOCINATIO: An Inquiry into the Knowledge of Architecture in Vitruvian Theory**
Hayri Dortdivanlioglu
Georgia Institute of Technology
- 307 /316 ■ **TERMINOLOGY AND GEOMETRY: Evolution of Chinese Traditional Architectural Drawing**
Lina Sun
The Bartlett School of Architecture
- 325 /336 ■ **THE BIRTH OF THE ORTHOGONAL CITY PLAN: Visual to Surveyed Representations of Rome from the 14th to 18th Century**
Ayse Aylin Tarlan
AA School
- 337 /345 ■ **ON SOLIDITY IN ARCHITECTURE: Ornament, Shadow, and Construction**
Laura Trazic
Ecole Polytechnique Fédérale de Lausanne

New Materials and Construction Techniques

- 43 /50 ■ **BENDING PARABOLAS: Formwork for Compression-only Structures**
Wesam al Asali¹, Thomas Reynolds² & Michael Ramage¹
¹University of Cambridge, ²University of Edinburgh
- 125 /135 ■ **TAPPING INTO URBAN RECYCLING FOR LOW-COST BUILDING ALTERNATIVES: Experimenting with Waste Cardboard Reuse in Architecture**
Julio Diarte
Pennsylvania State University
- 159 /167 ■ **A SUSTAINABLE ALTERNATIVE TO ARCHITECTURAL MATERIALS: Mycelium-based Bio-Composites**
Ali Ghazvinian
Pennsylvania State University
- 225 /231 ■ **DRESSMAKING TECHNIQUES FOR PNEUMATIC FORMS**
Virginia Elyn Melnyk
Tongji University, Clemson University

Divergence As:

Transformation and Mutation

- 19 /32 **A CAMPUS BIOGRAPHY**
Bader AlBader
University of Michigan
- 61 /69 **ARCHITECTURAL MUTATIONS OF INDIVIDUAL HOUSES IN THE SAHARA DESERT: Case of Algerian Sahara**
Yassine Mohammed Benyoucef
Andrey Razin Dionisovich
Peoples' Friendship University of Russia
- 259 /270 **DESIGNING 'SAFE' SCHOOLS: Identifying Areas of Research in Achieving School Safety & Security**
Michael S. Nowak
Pennsylvania State University

- 281 /288 **A STUDY ON COMMUNITY PERCEPTION TO IMPROVE THE URBAN GREEN SPACE DENSITY: A Case Study of Can Tho City, Vietnam**
Phuong Phi Pham, Se-Guy Oh
Chonnam National University
- 325 /336 **THE BIRTH OF THE ORTHOGONAL CITY PLAN: Visual to Surveyed Representations of Rome from the 14th to 18th Century**
Ayse Aylin Tarlan
AA School
- 355 /364 **FROM SEGREGATED TO INTEGRATED: The Evolution of Shading Designs in Marcel Breuer's Works**
Yuan Yao
Southeast University

- 95 /103 **RICHARD NEUTRA: Latin American Connections**
Fernanda Critelli
Universidade Presbiteriana Mackenzie

Interpretative Action

- 113 /124 **THE 'UNINTENDED' CITY: A Case for Re-reading the Spatialization of a Princely City through the 1898 Plague Epidemic**
Sonali Dhanpal
Newcastle University
- 137 /147 **WEAVING FABRICA AND RATIOCINATIO: An Inquiry into the Knowledge of Architecture in Vitruvian Theory**
Hayri Dortdivanlioglu
Georgia Institute of Technology
- 289 /293 **SIZA, KOOLHAAS, AND THE OTHERS: Notes on a Research into the Minutia of Architectural Experience**
Ana Luisa de Sá
University of Porto

- 317 /324 **OPERABLE WINDOWS, THERMAL COMFORT, AND INDOOR AIR QUALITY IN K-12 SCHOOLS: Identifying the Gap and Proposing Future Studies**
Helia Taheri, Traci Rose Rider
North Carolina State University

- 271 /279 **A PROLEGOMENON TO IMAGE-BASED HISTORIOGRAPHY: Forensic Architecture's Spatiotemporal Model and the Split-Second Event**
Nicholas Andrew Pacula
Yale University

Epistemological Strategy

- 79 /86 **GRAPHS, SETS AND COVERS; SEEING WHAT HAS ALWAYS BEEN THERE: Finding Common Ground between BIM Applications and Their Users**
Mehmet Sinan Bermek
Georgia Institute of Technology
- 105 /112 **POSTCOLONIAL POSSIBILITIES OF ARCHITECTURAL HISTORY: Questions and Concerns in reading the Urbanisms of the Global South**
Soumya Dasgupta
University of Illinois at Urbana-Champaign
- 179 /186 **THE FEASIBILITY OF NATURAL VENTILATION IN CHICAGO'S TALL OFFICE BUILDINGS USING DOUBLE-SKIN FAÇADES**
Yohan Kim
Illinois Institute of Technology

- 295 /305 **MACHINE LEARNING FOR ARCHITECTS AND DESIGNERS: Implementing Machine Learning into the Digital Design Process**
Adam Sebestyen
Vienna University of Technology, New Design University St. Pölten
- 347 /354 **SHAPE-CHANGING ARCHITECTURAL SYSTEMS: A Bottom-up and Top-down Approach for Developing Responsive Building Skins**
Elena Vazquez
Pennsylvania State University

Reframing Perception

71 /78 • **CHANGING WATERSCAPES: The Dichotomy of Development and Water Management Surrounding the East Calcutta Wetlands since the British-colonial Era**
Abhinandan Bera & Hong Wu
Pennsylvania State University

87 /94 • **OVERSEAS EXHIBITIONARY EVENTS AS THE DICTATOR OF CONTEMPORARY CHINESE ARCHITECTURE: "TU MU: Young Architecture of China" in a World Media System**
Dijia Chen
University of Virginia

169 /178 • **INSTITUTIONALIZING CO-PRODUCTION IN THE CONSERVATION AND RENEWAL OF RESIDENTIAL URBAN HERITAGES IN SHANGHAI: The Obstacles and Solutions**
Miao Hu
Tongji University

125 /135 • **TAPPING INTO URBAN RECYCLING FOR LOW-COST BUILDING ALTERNATIVES: Experimenting with Waste Cardboard Reuse in Architecture**
Julio Diarte
Pennsylvania State University

159 /167 • **A SUSTAINABLE ALTERNATIVE TO ARCHITECTURAL MATERIALS: Mycelium-based Bio-Composites**
Ali Ghazvinian
Pennsylvania State University

225 /231 • **DRESSMAKING TECHNIQUES FOR PNEUMATIC FORMS**
Virginia Ellyn Melnyk
Tongji University, Clemson University

149 /157 • **OUTSIDE KNOWING: Accessing Alterity in the Nocturnal Urban Landscape**
Clarie Downey
University of Limerick

193 /202 • **THE MICROGEOGRAPHIES OF SOCIAL JUSTICE: Architect(ure) and Social Housing**
Kourosh Mahvash
University of Waterloo

241 /250 • **SYSTEMS EVERYWHERE: On the Incorporation of the Vocabulary of Systems Sciences in Architectural Discourse During the Second Half of the 20th Century**
Michael Moynihan
Cornell University

43 /50 • **BENDING PARABOLAS: Formwork for Compression-only Structures**
Wesam al Asali¹, Thomas Reynolds² & Michael Ramage¹
¹University of Cambridge, ²University of Edinburgh

233 /239 • **PERFORMANCE-BASED FACADE DESIGN TOOL: Approach for Automated and Multi-Objective Simulation and Optimization**
Mahsa Minaei
University of Massachusetts Amherst

Expansion of Possibility

51 /59 • **HOW ENERGY MAKES A DIFFERENCE ON THE MORPHOLOGY OF SPACE**
Mark Balzar
University of Applied Arts Vienna

187 /191 • **A CRITICAL INQUIRY INTO THE 'PROBLEM' OF STOPPING IN ARCHITECTURE**
Skender Luarasi
POLIS University

203 /213 • **MECHANOLOGICAL DYNAMICS IN JACQUES LAFITTE AND GILBERT SIMONDON**
Marisabel Marratt
Georgia Institute of Technology

337 /345 • **ON SOLIDITY IN ARCHITECTURE: Ornament, Shadow, and Construction**
Laura Trazic
Ecole Polytechnique Fédérale de Lausanne

33 /41 • **RIVAL GEOGRAPHIES: Race-Relations, Power and National Planning In Postwar America**
Shahab Albahar
University of Virginia

215 /223 • **DEVELOPING 'URBAN JUNGLE' AS AN INTEGRATED MODEL OF SURVIVAL: Learning from Nature in War Zones**
Yasser El Masri
Georgia Institute of Technology

251 /258 • **AGENT BASED SEMIOLOGY: Simulating Contemporary Office Occupation Patterns with Simplified Social Models**
Robert R. Neumayr
University of Applied Arts Vienna

307 /316 • **TERMINOLOGY AND GEOMETRY: Evolution of Chinese Traditional Architectural Drawing**
Lina Sun
The Bartlett School of Architecture

Destabilizing Gap

- A** 19 **A CAMPUS BIOGRAPHY**
/32 Bader AlBader
University of Michigan
- 33 **RIVAL GEOGRAPHIES: Race-Relations, Power and National Planning In Postwar America**
/41 Shahab Albahar
University of Virginia
- 43 **BENDING PARABOLAS: Formwork for Compression-only Structures**
/50 Wesam al Asali¹, Thomas Reynolds² & Michael Ramage¹
¹University of Cambridge, ²University of Edinburgh
- B** 51 **HOW ENERGY MAKES A DIFFERENCE ON THE MORPHOLOGY OF SPACE**
/59 Mark Balzar
University of Applied Arts Vienna
- 61 **ARCHITECTURAL MUTATIONS OF INDIVIDUAL HOUSES IN THE SAHARA DESERT: Case of Algerian Sahara**
/69 Yassine Mohammed Benyoucef, Andrey Razin Dionisovich
Peoples' Friendship University of Russia
- 71 **CHANGING WATERSCAPES: The Dichotomy of Development and Water Management Surrounding the East Calcutta Wetlands since the British-colonial Era**
/78 Abhinandan Bera & Hong Wu
Pennsylvania State University
- 79 **GRAPHS, SETS AND COVERS; SEEING WHAT HAS ALWAYS BEEN THERE: Finding Common Ground between BIM Applications and Their Users**
/86 Mehmet Sinan Bermek
Georgia Institute of Technology
- C** 87 **OVERSEAS EXHIBITIONARY EVENTS AS THE DICTATOR OF CONTEMPORARY CHINESE ARCHITECTURE: "TU MU: Young Architecture of China" in a World Media System**
/94 Dijia Chen
University of Virginia
- 95 **RICHARD NEUTRA: Latin American Connections**
/103 Fernanda Critelli
Universidade Presbiteriana Mackenzie
- D** 105 **POSTCOLONIAL POSSIBILITIES OF ARCHITECTURAL HISTORY: Questions and Concerns in reading the Urbanisms of the Global South**
/112 Soumya Dasgupta
University of Illinois at Urbana-Champaign
- 113 **THE 'UNINTENDED' CITY: A Case for Re-reading the Spatialization of a Princely City through the 1898 Plague Epidemic**
/124 Sonali Dhanpal
Newcastle University
- 125 **TAPPING INTO URBAN RECYCLING FOR LOW-COST BUILDING ALTERNATIVES: Experimenting with Waste Cardboard Reuse in Architecture**
/135 Julio Diarte
Pennsylvania State University
- 137 **WEAVING FABRICA AND RATIOCINATIO: An Inquiry into the Knowledge of Architecture in Vitruvian Theory**
/147 Hayri Dortdivanlioglu
Georgia Institute of Technology
- 149 **OUTSIDE KNOWING: Accessing Alterity in the Nocturnal Urban Landscape**
/157 Clarie Downey
University of Limerick
- G** 159 **A SUSTAINABLE ALTERNATIVE TO ARCHITECTURAL MATERIALS: Mycelium-based Bio-Composites**
/167 Ali Ghazvinian
Pennsylvania State University
- H** 169 **INSTITUTIONALIZING CO-PRODUCTION IN THE CONSERVATION AND RENEWAL OF RESIDENTIAL URBAN HERITAGES IN SHANGHAI: The Obstacles and Solutions**
/178 Miao Hu
Tongji University
- K** 179 **THE FEASIBILITY OF NATURAL VENTILATION IN CHICAGO'S TALL OFFICE BUILDINGS USING DOUBLE-SKIN FAÇADES**
/186 Yohan Kim
Illinois Institute of Technology
- L** 187 **A CRITICAL INQUIRY INTO THE 'PROBLEM' OF STOPPING IN ARCHITECTURE**
/191 Skender Luarasi
POLIS University

M	193 /202	THE MICROGEOGRAPHIES OF SOCIAL JUSTICE: Architect(ure) and Social Housing Kourosh Mahvash University of Waterloo
	203 /213	MECHANOLOGICAL DYNAMICS IN JACQUES LAFITTE AND GILBERT SIMONDON Marisabel Marratt Georgia Institute of Technology
	215 /223	DEVELOPING 'URBAN JUNGLE' AS AN INTEGRATED MODEL OF SURVIVAL: Learning from Nature in War Zones Yasser El Masri Georgia Institute of Technology
	225 /231	DRESSMAKING TECHNIQUES FOR PNEUMATIC FORMS Virginia Ellyn Melnyk Tongji University, Clemson University
	233 /239	PERFORMANCE-BASED FACADE DESIGN TOOL: Approach for Automated and Multi- Objective Simulation and Optimization Mahsa Minaei University of Massachusetts Amherst
	241 /250	SYSTEMS EVERYWHERE: On the Incorporation of the Vocabulary of Systems Sciences in Architectural Discourse During the Second Half of the 20th Century Michael Moynihan Cornell University
N	251 /258	AGENT BASED SEMIOLOGY: Simulating Contemporary Office Occupation Patterns with Simplified Social Models Robert R. Neumayr University of Applied Arts Vienna
	259 /270	DESIGNING 'SAFE' SCHOOLS: Identifying Areas of Research in Achieving School Safety & Security Michael S. Nowak Pennsylvania State University
P	271 /279	A PROLEGOMENON TO IMAGE-BASED HISTORIOGRAPHY: Forensic Architecture's Spatiotemporal Model and the Split-Second Event Nicholas Andrew Pacula Yale University
	281 /288	A STUDY ON COMMUNITY PERCEPTION TO IMPROVE THE URBAN GREEN SPACE DENSITY: A Case Study of Can Tho City, Vietnam Phuong Phi Pham, Se-Guy Oh Chonnam National University
S	289 /293	SIZA, KOOLHAAS, AND THE OTHERS: Notes on a Research into the Minutia of Architectural Experience Ana Luisa de Sá University of Porto
	295 /305	MACHINE LEARNING FOR ARCHITECTS AND DESIGNERS: Implementing Machine Learning into the Digital Design Process Adam Sebestyen Vienna University of Technology, New Design University St. Pölten
	307 /316	TERMINOLOGY AND GEOMETRY: Evolution of Chinese Traditional Architectural Drawing Lina Sun The Bartlett School of Architecture
T	317 /324	OPERABLE WINDOWS, THERMAL COMFORT, AND INDOOR AIR QUALITY IN K-12 SCHOOLS: Identifying the Gap and Proposing Future Studies Helia Taheri, Traci Rose Rider North Carolina State University
	325 /336	THE BIRTH OF THE ORTHOGONAL CITY PLAN: Visual to Surveyed Representations of Rome from the 14th to 18th Century Ayse Aylin Tarlan AA School
	337 /345	ON SOLIDITY IN ARCHITECTURE: Ornament, Shadow, and Construction Laura Trazic Ecole Polytechnique Fédérale de Lausanne
V	347 /354	SHAPE-CHANGING ARCHITECTURAL SYSTEMS: A Bottom-up and Top-down Approach for Developing Responsive Building Skins Elena Vazquez Pennsylvania State University
Y	355 /364	FROM SEGREGATED TO INTEGRATED: The Evolution of Shading Designs in Marcel Breuer's Works Yuan Yao Southeast University

Abstract: The university, as an institution and as a space, is complex. A middle scale outside the comfort zone of architects, the campus bridges between the architectural and the urban. In response to professional pressures on architects, the study of campus planning emerged in the mid-twentieth century as a technocratic concern. The campus became a spatial type worthy of analytical attention and epistemic production. The functionalist approach to campus studies eventually gave way to more academic and less instrumental interests in the subject. To take stock of the development of the conceptualization of the campus as an object of analysis, I utilize the biographical method as a lens through which to read the differentiation within the field. This essay vicariously traces the contours of the campus' discursive landscape by focusing on the oeuvre of the discourse's prime inciter to discourse, Richard Dober. Through a close reading of his monographs, a textured picture of campus studies emerges; the discourse first coalesces around modernist, functionalist, and subsequently international concerns about the efficacy and adequacy of the spatial provisions accorded to rapidly expanding higher education. This is followed by a discursive turn towards more humanistic concerns like history and art, ushered by the publication of Paul Turner's seminal history of the campus in the United States. Dober was not immune to this discursive shift, but took it in stride, producing many books attempting to reconcile his rationalist, modernist predilections with the ascendance of lyricism and beauty as core analytical concerns. His oeuvre developed and expanded, incorporating campus history and aesthetics as primary interpretive threads. The ardent functionalist of yesteryear had to adapt and assume a humanistic outlook in his later years. In sum, campus discourse's story is a bipolar one, jumpstarted by modernist concerns spearheaded by Dober only to later be inflected by the Turner plot point towards scholarship in the vein of that produced by historian-aesthetes. Because Dober lived, worked, and wrote prolifically through all this, his collective works serve as an index of the evolution and differentiation of the campus discourse, and his books as lampposts along the shifting discursive landscape of campus planning and design. This deep dive into Dober's oeuvre and its interfaces with discursive developments illuminates how his oeuvre is *reflected in* and *inflected by* the evolution of the campus discourse. Uniquely intertwined with the discourse, Dober's biography is an opportune proxy through which to sketch a biography of the discursive campus.

Keywords: Campus planning and design, higher education, Richard Dober, intellectual biography, discursive paradigm shift

INTRODUCTION

In 1960, *Architectural Record* published "Campus Planning: The Unique World of the University," an article authored by Eero Saarinen tackling the distinctive difficulties and opportunities of campus planning. Having spent the larger part of the previous decade unsuccessfully trying to turn his masterplan of the University of Michigan's new North Campus into reality, Saarinen's article was an attempt to salvage value from the experience by formulating campus planning guidance. The silver lining of his tribulations at Michigan was that he could pontificate on campus planning not simply as a field of possibility for architects but as a formidable challenge. Beyond procedural advice like recommending that universities retain their campus masterplanners for architectural design services, Saarinen enjoined campus designs that reconciled design ambition with design context. The essay was an inchoate attempt by one of the midcentury's most prominent architectural figures to consciously and

methodically approach the specific question of campus design. His contention was that the university campus is a unique architectural problem, warranting special attention and, by extension, the cultivation of specialized expertise. Saarinen would have been happy to see that no more than three years later a monograph on this topic had been published—Richard Dober's *Campus Planning*—but he did not live to see it.

Dober's book, the first comprehensive guide for campus planning, was the genesis of the specialized discourse prefigured by Saarinen's article. Described as a "landmark book" in the historical trajectory of campus planning (Crawford 2014, 26), this was the first of many books which the campus planner authored. By far the most prolific writer on the subject, he continued to write until his death in 2014. He was campus discourse's prime inciter to discourse. Dober's collective works thus serve as an index of the evolution and differentiation of the campus discourse. This essay surveys his

monography, perusing his books in order to situate them as lampposts along the shifting discursive landscape of campus planning and design. This deep dive into Dober's oeuvre and its interfaces with discursive developments seeks to illuminate how his oeuvre is *reflected in* and *inflected by* the evolution of the campus discourse. Intellectual biography here serves as a heuristic, not to produce a hagiography of an author, but a genealogy of a discourse.

1. A (SUB)DISCIPLINE FORGED IN THE FIRES OF MODERNISM

1.1. GENESIS OF THE CAMPUS DISCOURSE

Campus Planning was first published in 1963, at the height of what Clark Kerr has described as the golden age of American higher education (Kerr 2001). Dober's acute awareness of this state of affairs, and his concerns about keeping up with higher education's expansion is evident in the book. He may have led with the assertion that "the physical forms which house (and will house) the process of education are self-evidently important," but it is clear that the general import of higher education need not have been belabored (Dober 1963, i). Rather, the book was written as a preemptive response to an anticipated crisis; Dober forecast a doubling in the demand for higher education and hence campuses. He wrote as "a general practitioner of the art of planning" in order to "suggest ways and means by which the development of campuses can be controlled, so that functional goals can be aesthetically expressed with least compromise to the past, the present and the future" (i).

At its core, Dober's book is a pragmatic guide for campus planning that does not neglect aesthetics. It was conceived as a foundation which university planners and designers could build on and adapt to their particular needs and challenges. The first two words in the body of the book—"Desperate and unprecedented" [original emphasis] (3)—underscored at the outset that campus planning is no luxury, that impending was an immense challenge demanding action. At the time, American higher education was increasingly taking on more students and had pivoted its attention to science and technology, an academic territory then largely uncharted. These developments were not unique to the United States, as many other nations were undergoing their own higher educational transformations. Dober was disconcerted that many institutions gave no long-term consideration to their physical environments. His book is a university planner's guide for the perplexed, an application of systematic reason to a hitherto undefined set of institutional activities. It was the first clear mark of the professionalization of campus planning.

Dober was a modernist whose book was underpinned by rational functionalism. Divided into three sections, the book first defines campus planning and traces its history, then analyzes the campus into its programmatic components, and provides guidelines for planning the expansion of extant campuses and developing new ones. Dober conceived of the professional practice of campus planning to be a departure from a predominantly romanticist past. Tracing the development of campuses in the US from the colonial period to his present, he highlighted the University of Virginia as a foundational moment, a juncture at which campus planning became a purposive endeavor, a calling. It was not this exemplar's aesthetic character per se that was critical, but its production as a comprehensive, rational, planned project. For Dober, the problem facing campus planning was "the dominance of style over plan;" style embodied the past, while plan gestured towards the future: "Plan here does not mean the physical continuity in contiguous structures . . . it is rather the dominance of site and program over facade" (Dober 1963, 34-40). Differentiating between types of plans with regards to programmatic and spatial specificity, temporal spans, and scale, he situated planning at the interface between program and design. He admitted that his guidelines were necessarily subject to adaptations demanded by every university's particular circumstances:

This book is a synthesis of current events which I have selected to weave together as a graphic outline of a flexible approach to campus planning. The synthesis is neither gospel nor cookbook. The techniques described should be selectively applied and adjusted to the changing situations which are unique to the individual institutions. The results that can be expected from the design of structure (planning) are different from those that can be expected from the design of content (architecture). Ideally, of course, one act activity melds into the other. (Dober 1963, 308)

Dober's book constituted a detailed and thorough handbook for practitioners, peppered with American examples from across various periods and geographies. It was rich with images that illustrated his various points. Acknowledging the absence of a theory of campus planning, but settling not for an ad hoc pragmatism, his book struck a middle ground, serving as a reference which was both methodical and flexible.

1.2. GOING PUBLIC, GOING GLOBAL

Dober did not simply write *the* book on the practice of campus planning but was also engaged in service of the international sort. Keen to learn from the postwar expansion of higher education in the United Kingdom, Educational Facilities Laboratories commissioned Dober to undertake a study of British campus planning

in "anticipation that this ferment might yield ideas pertinent to the American scene" (Dober 1965, 5). The study was published in 1965 as a short, illustrated book titled *The New Campus in Britain: Ideas of Consequence for the United States*. Dober analyzed the campuses of six new postwar universities, as well as two expanding long-established universities, in hopes of applying in the US what was learnt from campus building experiences in Britain. The lessons observed in this "design laboratory" include the flexible adaptation of American and European design trends, programmatic cross-fertilization producing "continuous teaching environment[s]," and the reduction of anonymity in large institutions (7-9). The kingdom's young modernist academic spaces and (mega)structures were celebrated for their internationalism, functionalism, flexibility, and novelty.

Dober was not the only author at the time to celebrate practice. Campus planning and design was a subject of common, if niche, interest in architecture circles. In 1972, Mildred Schmertz published a compendium of campus building studies originally published between 1966 and 1970 in *Architectural Record*, where she was an editor. She prefaced the book with the notion that universities' newfound but established awareness of the importance of campus planning has created an attractive market for architects and planners, going so far as to effusively claim that campus work "comprises some of the[ir] best work" (Schmertz 1972, vii). Schmertz also acknowledged a change in campus project scale and time span from piecemeal accretion over time to rapidly constructed megaprojects. Yet, her book addressed mostly new, single buildings added to extant campuses. It focused more on additions to campuses, rather than addressing campuses as new or extant wholes. The book surveyed various campus building types, providing specific information about specific buildings, including plans, sections, details, and sometimes even execution sequences. Schmertz's book was a vehicle for built case studies, a typology of campus architecture. It was not a campus typology, though. Only two chapters addressed the scale of the campus: "The single building or building complex designed as part of the campus master plan" and "Architecture which gives a campus the unity of a single building." As is evident from these section titles, the campus as conceived by Schmertz cannot be disentangled from architecture. In this conception, the campus emerges as an epiphenomenon of architecture: "A building, essentially a group of interrelated solids, will be considered by its architects as a group of interrelated voids as well, because in the hands of a skilled designer these voids become well-scaled open spaces—courts, malls, places, and gardens—adding greatly to the campus environment" (85). Campuses

are but "large architectural compositions" (165). Despite touching upon the overall order of some campuses, the book's focus is essentially atomistic, profiling ostensibly well-designed academic buildings, in contrast to Dober's comprehensive and methodical analysis of the campus type. Emerging out of *Architectural Record's* journalism, Schmertz's book is geared towards professional consumption, constituting what Dober had elsewhere described as "a collection of good photographs of good architecture" that would find a happy home on an architect's coffee table (Dober 1963, i).

The journalistic interest though no doubt a boon to the nascent campus planning discourse, Dober was more invested in producing rigorous, data-driven knowledge. He edited the Community Development book series, a collection "of over 40 titles including technical and reference books for the planning and design professions," published by the now defunct academic press Dowden, Hutchinson & Ross (Dober n.d.). The series included the volume "Planning Buildings and Facilities for Higher Education" which was attributed to the United Nations Education, Scientific, and Cultural Organization (UNESCO) but, for the most part, written by the Architects Co-Partnership of Potter's Bar, UK. This 1975 book was based on the same premise as Dober's, but now globalized: expansion in the provision of higher education across the world requires the physical expansion of its spaces. However, this expectation butts against the "new realism" of higher educational planning in the developing world: higher education is much too costly to be a priority in strained economies, and when it is a priority, the vocational is sought over the academic (UNESCO 1975, 1). The book therefore took the position that campus planning cannot be cleft from either educational or economic policy, that it is an intermediary between state policy and building construction. The book's purpose was to collect and synthesize the wisdom culled from existing literature and from the experiences of a few states and make it available to all states, especially developing countries, as well as institutions around the world.

Campus planning was here understood as a project management challenge of which time and cost effectiveness are the critical factors. To help states and institutions overcome this challenge, the book sought to be a comprehensive guide to the practice of higher educational planning from the macro scale to the micro. It triangulated between three actors—the client (colleges or universities), the design consultant (architects and planners), and the coordinating authority (regulatory and funding bodies) (figure 1)—and advocated network planning because it comprehensively takes into account any project's multiple parallel and intersecting strands. Though it professed that university planning "is not

something which can be definitively summarized in the way that a manual gives the procedures for flying a jet aircraft" (7), the book attempted to provide a methodical set of instructions for the practice of planning, which it divided into six stages:

1. Policy, which encompasses socioeconomic strategy at the national and regional levels
2. Planning, which encompasses masterplanning at the institutional level
3. Primary brief, which encompasses delineating preliminary programs, floor areas, and building masses
4. Secondary brief, which encompasses incorporating specific user requirements
5. Primary implementation, which encompasses design development based on the primary brief
6. Secondary implementation, which encompasses full construction drawing sets and construction administration

Sequentially working through the whole process, the authors dedicated a chapter to each procedure which was further broken down into smaller steps. The book also provided a series of ready-to-use flow charts, templates, checklists, and forms. Key amongst these were the "area analysis data sheets" which, if well utilized, should have ensured that project costs were controlled and kept to a minimum (16).

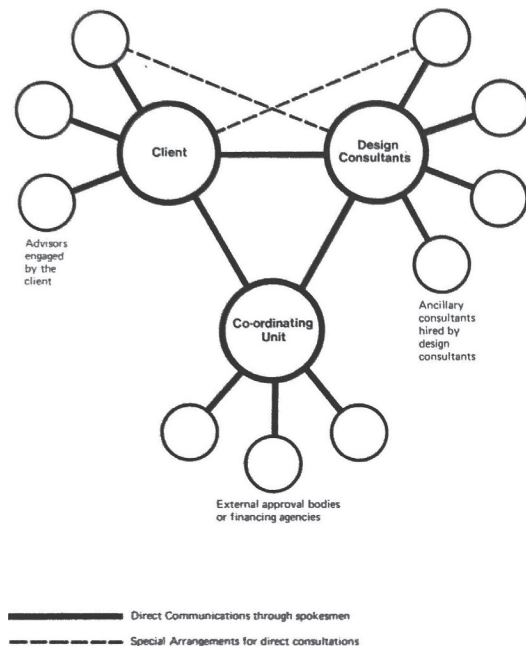


Figure 1: UNESCO's diagram of the relationship between various campus planning actors and stakeholders. (UNESCO 1975, 4)

Despite its emphasis on numerical data and calculability, the book did not claim to set international standards since that would have been futile in the face of sweeping institutional and cultural variability internationally. Rather, it sought "to provide Unesco Member States with a working tool that enables them to develop their own 'norms' and practices in response to their own needs and within the range of resources available to them" (22). Understanding higher education to be a dynamic enterprise, it eschewed determinism of both the instrumental and aesthetic sorts, eliding the binary of the functional versus the beautiful for the flexible. Building flexibility into the design is especially important during the primary brief phase, the work of which is to be limited to design technocrats who are thought to be better at balancing everyone's needs than academics, no matter how vocal. In contrast to the latter's perceived myopia of vested interests, the former are professionals who are likely to think of a building's long life beyond a single set of users. Only later, during the secondary brief stage, should users be brought into the planning and design process, a position the book admitted was controversial (73).

The book was polyvalent, at once a textbook, a handbook, and a resource book to be copied, printed, and marked up. And because it did not seek to be a unitary source of information, it was accompanied by a supplementary volume which offered planners data from around the world with which they could compare their own projects. Titled *Planning Standards for Higher Education Facilities*, the supplement was published four years after the guide. While the earlier book was about "planning procedures and the effective interaction of architects, administrators, academic personnel and others," the supplemental book focused on data dissemination by "reproducing a considerable quantity of technical information" from a handful of member states (UNESCO 1979, 5). Notwithstanding its title, the volume's purpose was to provide planners with "yardsticks," not standards. It was not a precis of UNESCO's views on the subject, but a standardized compendium of various national practices; the data was culled from 12 countries across six continents. The global scope of the volume was a reflection of the international composition of its team of authors, who hailed from Iran, Peru, and the Netherlands.

One major challenge the book tackled was the experience of higher educational planning as a "lonesome adventure," particularly in developing countries establishing their first universities (9). Though the book presented technical information from various countries in standardized, comparable, machine-readable "data sheets" (figure 2)—albeit difficult for humans to readily read—the authors accepted that

differences in planning practice abounded within and between countries and sought to document that diversity in the form of rote, descriptive rather than prescriptive specifications. Dober's illustrated exegesis of functional spatial composition reads as lyrical prose in juxtaposition to this supplement's singular accounting of spatial metrics. There was but a single drawing in the whole publication (185). It was a book composed exclusively of charts, tables, graphs, and numbers collected using standard templates—functionalism on steroids. The supplementary volume was envisioned as an intermediary between abstract, high-level guidance and developments on the ground around the world. This higher educational planning almanac was to serve as a distilled, international technical library which closed the feedback loop between UNESCO's guide and local practices; as countries built more campuses and accrued more campus building experience, new data was to be added to the compendium which was to feed into the formulation of more precise and effective generalizations about planning best practices to be published in future UNESCO guides (UNESCO 1975, 23). This was an ambitious scheme. Suffice it to say, no further guides were produced.

One study from which UNESCO's guide may have culled is *Campus Design in India*. Published in 1969 and sponsored by the United States Agency for International Development, the book sought to generalize from the "experience of a developing nation." Its authors, Achyut Kanvinde of India and H. James Miller of the American Midwest, were international collaborators who had studied at different universities in the US and crossed paths while practicing campus planning in India. The volume, well-illustrated with monochrome photographs and diagrams, is a distillation of the lessons they learnt while working on campus projects there. Though their premise in writing this book was identical to the one that motivated both Dober's earlier book and UNESCO's later guide—"keenly aware of the urgency of the hour and fully comprehend[ing] the manifold problems of the nation of India in trying to wisely utilize scarce resources in university campus development"—they set out not to simply survey the state of campus planning in the subcontinent, but to write "an authoritative guide for administrators and professionals who are charged with the responsibility of campus design in India" (Kanvinde and Miller 1969, 161). The authors did not present this focus on higher education simply as a modern fixation, but tied it to Indian history and culture, often citing Vedic traditions. The assertion of cultural continuity, however, did not negate that India's postcolonial moment was pregnant with revolutionary potential. National independence brought about the nation's self-responsibility for rapid socioeconomic

development, including developing and expanding higher education across the country. Economic pressures notwithstanding, the understanding was that new universities would inevitably be built, and existing ones expanded, so the resources of developing countries would be better put to inspiring use than to depressing use. The authors' intent was to spell out a planning and design process that results in spaces of higher education that live up to national aspirations, especially because the construction of new campuses could become "a disastrous waste of resources, unless properly directed, due to the costly specialized and permanent nature of a college or university campus" (14).

Environmental determinism was the basis of Kanvinde and Miller's enjoinders. Higher education's physical environment is critical because it is the foundation of a series of links to progress at the macro scale: India needed a socioeconomic revolution; mass higher education was the means to that revolution; campuses are where the process of higher education takes place. The authors asserted the interdependence of the quality of the campus environment, the educational experience, and the graduate: "quality of academic content is most important, but it depends on the quality of the social-living-work-study environment of a college or university campus" (15). Yet despite their importance for citizen development, such spaces were not readily available. There was a huge gap between the number of university seats in the country and its college-age population; while that ratio in the US was 40% in 1965 and projected to be 18% in the UK by 1980, India was at a meager 2% (18). The many spaces built to address this gap must be well-designed because "*intensive mass education requires good architecture to provide an environment that will enhance the efficiency and well-being of those involved*" [original emphasis] (20). The fact that rapid massification of higher education was needed in one of the world's most populous countries superscaled the urgency of the spatial emergency.

The paucity of space was compounded by wanting expertise. Kanvinde and Miller were critical of the campus planning and design status quo in India, particularly the fact that this process was generally undertaken by university engineers and governmental public works departments, parties they deemed inadequate to the grand task at hand. These actors tended not to take seriously architectural qualities and environmental comfort, heedless to the supposition that the "campus environment can spell the difference between a fine university and a mediocre one" (20). They would also eschew precision and preemptively exaggerate their space requests in case reductions became necessary later in the process, an imprudent

24

practice given the reality that a "nation with scarce resources cannot afford such wastefulness" (20). Here, environmental determinism was coupled with economic exigency. Poor architecture, especially at the scale of a campus, is an economic drain in the long run. Professional campus planning and architectural design undertaken by specialized experts was the authors' remedy. The book thus triangulates between professionals (architects and planners) and two classes of decision makers, government officials and institutional administrators. To emphasize the dependence of spatial outcomes on enlightened institutional leadership, campus design was defined as being "dependent upon a correct *process* for a successful *product*" [original emphasis] (6).

The successful product here sought was an "island of excellence" that maintains "an ambivalent position, balancing itself carefully between commitment and detachment," between being a "regional service station" and an ivory tower (24). The authors compared the campus to a miniature city, seeing similarity in both models' provision of comprehensive services to their inhabitants, but seeing divergence in the former's eschewal of the commerce motive that undergirds life in the latter. The single-minded pursuit of learning critically differentiates campus living from the cacophony of city life. They even went so far as to assert that the campus "should ideally be a quiet, comfortable oasis apart from the normally busy, noisy, congested world. In this sense a campus should be more like a residential suburb or park than a city" (25). Here, the authors valorized a pastoral model reminiscent of the Jeffersonian ideal. However, they qualified this with the assertion that a campus must not be disconnected from its context, but actively engaged in solving its community's problems. To reiterate the sociality of this spatial actor, the authors referred to the "*campus university*" as a distinct, ideal type of institution, one with a space of its own wherein students encounter real life by learning to live alongside countless others (25). To ensure that the campus supports such social interaction and avoids mediocrity, Kanvinde and Miller explained that its design must account for the prospects of growth and change over time, avoid being too big so as not to be walkable, and be sensitive to human comfort and environmental psychology. By designing the campus holistically and integrating both its natural setting and landscaped elements, elusive beauty may be attained.

In order to be able to achieve this ideal, the planning and design process must engage and attain the support of stakeholders at multiple organizational levels. The authors devoted a considerable amount of the book to walking through this process and its organizational interfaces, starting with institutional

structures, through site planning and building design, to construction administration, all with a specific focus on the Indian context and the actors, regulators, and agencies one would encounter there. Dober's two aforementioned books are cited frequently here. Working off his insights, Kanvinde and Miller emphasized that campus design is a process that requires diligent institutional effort as well as trust in expertise; administrators must choose a competent and conscientious architect who they must empower to shepherd the process towards a "creative synthesis" (60). To substantiate that attaining a fine campus is feasible, the book ends with a series of brief case studies, first of Indian campuses, then international ones. The series starts off with four cases from ancient Indian history, through one case from the Delhi Sultanate, to fourteen Indian campuses established during the 20th century. All international examples are of campuses in the UK and North America, except for Walter Gropius' design for the University of Baghdad. The common thread across almost all these highlighted cases is that they were products of collective efforts to enact living-learning environments envisioned as unified wholes. As successful products of campus design processes, they each embody quality and contextuality. On the application of these lessons to the national juncture during which they were writing, Kanvinde and Miller averred that the successful Indian campus is one that is grounded in its history but attuned to the moment, reconciling Vedic personal discipleship with modern mass education (158).

2. DOBER AND THE HUMANISTIC TURN(ER)

2.1. A NEW MAGISTERIUM

The attunement to history in the study of the campus type marks a turning point in the burgeoning discourse. Richard Turner's 1984 book, *Campus: An American Planning American Tradition*, is the most cited book on the subject. Just about every author who has since written about campuses in the United States has referenced his canonical tome. Until the publication of Turner's volume, no book covering the subject of campuses was more comprehensive than Dober's debut monograph. More momentous than *Campus*'s scope was the new epistemic lens it brought to bear on the subject.

While working on an exhibition of Stanford University's architecture in 1976, Turner discovered that no history of the American campus had been written (Turner 1984, ix). Eight years later, he published his seminal text to fill this historiographical gap. Prefacing the book with a discussion of Jefferson's "academical village," Turner explained that American higher education's recognition of colleges as "cities

in microcosm" resulted in a uniquely American institutional type: the campus. The US acquired the British collegiate model, a living-learning arrangement in which the college hosted the breadth of a community's activities, unlike the solely academic concerns to which continental European universities catered. However, the early American college differed from the British model in three ways: first, its autonomy versus the congregation of colleges into universities in the UK; second, the marriage of college and country versus the urban character of British universities; and third, the spaciousness of freestanding buildings in a landscape versus Britain's cloisters. Having distanced itself from the city, the American college had to reconstitute it. "The romantic notion of a college in nature, removed from the corrupting forces of the city, became an American idea," Turner explained, "But in the process, the college had to become even more fully a kind of miniature city. And its design became an experiment in urbanism" (4). The word *campus* evolved from its original Latin meaning of field at Princeton to denote the entire university property and finally became a nationwide index of an academic *genius loci*. Evolving from a reference to pristine green land into a pairing of architecture and landscape, campus came to denote a synthesis which produced a veritable academic sense of *place*.

In his survey, Turner emphasized the interrelationship of ideal and design, focusing on historical examples as idealistic proposals rather than as compromised realizations. This approach foregrounded the projective nature of the architectural plan. Challenging the idea that campus planning was rare (and that the University of Virginia was an exception) and that campuses tended to grow haphazardly (and were thus worthy of scholarly neglect), he asserted that campuses have always been subject to design and projection, setting out "to examine the English collegiate tradition in America as a relatively isolated subject" (6). Despite English and, later, German influences on American higher education, the planning of universities was not a slave to European inclinations and trajectories as most architecture and design trends in the US were. The campus was subject to distinctly American social, cultural, and economic conditions. "In some ways," Turner stated, "architectural developments can be seen as expressions of the educational ones" (15). American campuses manifest the evolving American understanding of higher learning.

The history of campus planning and architecture that he traced followed a trajectory which paralleled the evolution of the American nation-state, from the colonial period to the post-Second World War period. The turning points in American history find their architectural and planning reflections in the institutions of higher

education. Every age of the American socio-political experiment produced its corresponding campus. In both city and country, the early colonial colleges gave way to universities for a new, vast, expanding nation. The institution of the land grant model and the rise of the City Beautiful movement produced new campuses, just as revivalist impulses took inspiration from colonial and Gothic precedents. The end of campus historicism augured by Modernism was soon challenged by Postmodernism. This historical evolution reflected the American campus' "peculiar state of equilibrium between change and continuity" (304). The campus has been at once conservatively historicist and experimentally projective, growing out of a European tradition but producing a tradition of its own. Turner summed up its meandering development aptly:

The history of the American campus reveals the varied and innovative forms this expression can take. These have included the open quadrangles of colonial Harvard or the College of William and Mary, forthrightly part of the towns they were in and of the society whose values they represented; the nineteenth-century college in nature, often poised on a hill, surveying the "New Zion," as Union's President Nott called his vision of America; the informal, park-like campus plans of the early land-grant schools, reflecting populist values in reaction against the elitist formality of the classical college; the Beaux Arts organization of the new American university, with its complex and orderly system of parts; the revival of the English medieval enclosed quadrangle, expressing the resurgence of conservative collegiate values; and the recent campus plans generated by circulation patterns, reflecting the fluid and unpredictable nature of contemporary education. (Turner 1984, 304)

Growth and change notwithstanding, Turner affirmed that the American campus maintains its sense of place, physically embodying academic spirit, institutional character, and communal ideals.

The idea of the campus in Turner's work is entangled with American exceptionalism. His study was concerned only with the American campus, taking a chronological historiographical approach coupled with morphological analyses and aesthetic criticism. In contrast to Dober's chief focus on practice, Turner's was a work of pure scholarship. Here, the discipline/profession divide was patent: Turner's study was an academic history of campus, while Dober's emerged out of a planning practice. The campus discourse, hitherto functionalist in orientation, took a historical and aesthetic turn in the wake of Turner's monograph. And Dober was not immune to this new discursive orientation.

2.2. PLACEMA(R)KING CAMPUSCAPES

After two decades focusing primarily on his practice and during which he produced a couple of reports for the Educational Facilities Laboratories, Dober returned to

authorial work in the early 1990s, publishing three books in the span of a decade. The first, published in 1993, reiterated that campus planning as an art sublimates into design. As higher education had by then become ubiquitous in the US and around the world, *Campus Design* was a plea for universities to provide physical environments that combine “the visionary and the pragmatic,” ones that “will resonate with reality, without compromising ingenuity or idealism,” eschewing “neither art [n]or function” (Dober 1992, 4). Because higher education is both complex and diverse, Dober brought together insights culled from traditional town planning, urban design, participatory planning, and landscape architecture. He divided the objects of campus design into buildings, landscapes, and circulation systems, and termed the process of designing with them placemaking and placemarking. He cited as a foundational influence Kevin Lynch’s seminal work on environmental cognition (1960), applying his insights to university campuses. No longer ascribing prime value in campus planning solely to functional precision, Dober came to terms with the bounded omniscience of the designer, highlighting as positive the field’s naturalization of equivocality: “The master plan (fixed and static) gave way to the campus plan (flexible and dynamic). Process and plan became interdependent” (5). The adaptable had come to replace the rigid, the iterative taking the place of the linear.

Effusively citing Turner’s book, Dober asserted that campus planning is “not an arcane art” but is alive and well (5). A combination of “placemaking” and “placemarking,” campus design sculpts both the spatial and the material to produce place on site. It goes beyond the *parti* and the diagrammatic masterplan to tangible, material design decisions on the ground. Dober defined placemaking as the process of schematic design which takes context and program into account to produce an overall campus plan. Finer grained is placemarking, the combination of physical elements—landmarks, styles, materials, and landscapes—to give a campus a coherent image. This critically involves utilizing design artefacts as cultural currencies and mediums of interpersonal and transhistorical exchange. Placemaking addresses overarching physical form and organization, while the placemarking engages the meanings and experiences afforded by design decisions (figure 3). Discerning a gap in the campus literature regarding the latter, Dober’s book was explicitly concerned with placemarking.

Since campus planning, or here placemaking, has been much studied and widely accepted, Dober affirmed the need for a dedicated and detailed treatment of “placemarking aspects of campus design without subordinating the importance of the broader plan as a matrix that co-ordinates the individual design

actions into a unified scheme” (6). Paying attention to placemarking is important because it produces contextual authenticity, which balances continuity and change, helps attract students and patrons to the institution, and remedies what Dober considered to be the regrettable physical state of universities. In advocating campus beauty and vitality, Dober spoke of an “ecological ethics” by which architecture and landscape are integrated into an evocative place. Terming his book a “professional reference work,” he started with a survey of exemplars, which he had visited, as models from which to learn. The bulk of the book is dedicated to examining each of his four elements of placemarking, accompanied by historical and contemporary examples. He concludes with a chapter on placemaking, explaining how to make the most of these elements: “Placemaking binds the individual campus design actions into a coherent entity or, at least, makes known the context into which individual actions can be best fitted for optimum effect” (8). The campus must amount to something more than the sum of its aforementioned parts. In effect, the campus is an embodiment of an integrated plurality—a community—and its design “in this respect is the collective stewardship of a communal art form” (8).

Campus Design was published after the passing of the golden age, at a time when university development was a more sobering prospect. Despite its applicability to campus design generally, the book was geared towards the revitalization and renewal of extant campuses, not their expansion nor the establishment of new ones. Dober conceived of campus design as a dialectic of placemarking and placemaking, of

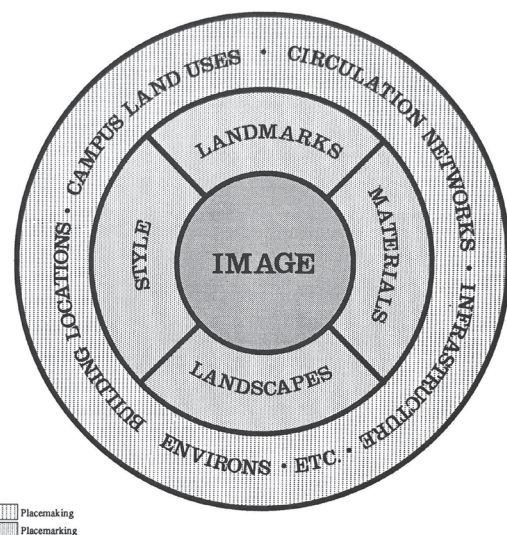


Figure 3: Dober’s conceptual diagram of campus design factors. (Dober 1992, 12)

architecture, landscaping, and sitework on one hand, and planning on the other. The two were not conceived as independent activities, but as analogous to a "mobius strip" (229). Dober provided adaptable methods applicable to diverse contexts and situations, albeit, centered on the West. This is attested by the lineage in which he situated the campus: done well, campus design ascends to the status of "civic art," becoming a worthy successor to the great European public spatial types: agora, forum, cathedral, town square, palace, and "centers of commerce, transportation, and government" (280). Dober's underscoring of the campus type's public and aesthetic significance followed the example of a book published the year before, *The Campus as a Work of Art*. Thomas Gaines wrote it to enjoin the appreciation of campuses as artworks and to appraise the artistic quality of campuses in the US. With aesthetics having taken center stage in the discourse, *Campus Design* was an effort to apply a method to the subjective, a synthesis Dober spent much of the rest of his life articulating.

On the heels of this dialectical approach, came a book focused on major elements not explicitly encompassed in either of Dober's dual categories, but is unmistakably present in his grand analogy: architecture. Campus buildings mediate between the overarching campus plan and the details of open space design and landscaping. Dober's *Campus Architecture: Building in the Groves of Academe* served to instrumentalize historical knowledge towards the development of new campus architecture. Building off the assertion that campuses have succeeded the great public spaces of the past—"three-dimensional record[s] of aesthetic achievement . . . indicative of their period and its aspirations"—he posited the campus as a planned and designed space, a marked and made place, melding the old and new—"nouveaux et anciens ensemble" (Dober 1996, x). American architecture had assumed the mantle of great public space, Dober asserted, and the campus became America's earliest contribution to the discipline of architecture.

Campus planning and development is an environmental art in its most expansive sense, an aesthetic, social, and cultural phenomenon worthy of study and practice. The design of a campus landscape is just as significant as the design of its buildings. When it comes to campuses, Dober pronounced landscape architecture "the consummate companion of admirable buildings" (ix). Architecture and landscape, together, make a campus. Dober defined campus as "an ensemble of buildings, landscapes, and infrastructure used for higher education, as it exists and as it is planned . . . a cachet implying an ordered design, special and coherent" (166). The plural is integral to the idea of the campus; a group of buildings

standing alone together on a single plot of land do not constitute a campus. An integrated plurality, a cogent set of interrelationships, is necessary to produce a whole that transcends its parts. For Dober, therein lies the importance of Architecture; it brings all the parts into a harmonious spatial symphony ready for use. He also provided another, prescriptive definition of campus architecture: "buildings and landscapes synergistically engaged and integrated as projects which are situated in paradigms planned and designed for higher education" (175). As supra-architectural compositions, these paradigms run the gamut between the "Apollonian" and the "Dionysian," that is the formal and the organic (197). In this definition, the campus is an intentional construct and its guiding hand is the architect's, through whose abilities a dignified place is fashioned out of given space, land, and material.

A major focus of Dober's in this book is the adoption of Modernist architecture as a spatial vehicle for higher education. He asserted that the visionary drive of Modernism aligned with higher education's civilizing mission. Modernism's ascent as the wellspring of collegiate architecture during the 20th century is a reflection of its agility in performing as a "machine for learning" just as it claimed to be a machine for living (8). Modernist architecture's economy did not sacrifice aesthetics; it was both relatively cheap and arguably beautiful. On a cultural register, Modernist rational functionalism mirrored rugged American pragmatism. Modernism's liberating aesthetic fit perfectly with the American ethic of liberty. Dober traced the development of Modernist campus architecture along three stages: early Modern campus architecture was typified by austere, sanitized boxes, which gave way to mid-Modern mannerism with its textured and sculptural effects applied to the box, while late Modern architecture was more elaborate, often segmenting and deconstructing the building form and differentiating its masses, an approach that has become the foundation of much contemporary campus architecture. As Modernism took root in American campuses, it became the quotidian architecture of higher education.

Modernism, however, did not erase the extant architecture of American campuses. It simply populated them with a new generation of buildings, standing in contrast, and sometimes in tension, with the old guard. Dober explained that the competition between traditional and modern architecture reflected the broader conflicting cultural attitudes of conservative sentimentality and progressive honesty. Campus architecture continues to be an actor in this dialectic with history. Dober contended that the only universal attribute of American campuses is their diversity. That he prescribed a transparent campus planning and

design process applicable to any and all campuses did not mean that they were to be homogenous. Nor should this approach be limited to higher education; though he defined the campus primarily as an educational type, he presciently admitted that the concept “may have useful application for any large group of buildings and landscapes constructed over time and intended to be mutable environments responding to social and cultural needs” (166-7). It is this functional flexibility, contextual adaptability, and aesthetic coherence that makes the campus as potent a spatial model as it is.

Dober's subsequent book, published at the turn of the century, focused on that consummate companion of architecture. In line with Dober's Modernist functionalist predilections, *Campus Landscape: Function, Forms, Features* applied an analytical treatment to the subject, unpacking campus landscape into its constituent parts. Like most of his previous books, this one constituted a response to the lack of books on the topic of campus landscapes. It was a comprehensive, illustrated survey and guide for the design of “the green environment that situates, serves, and symbolizes higher education” (Dober 2000, xv). He acknowledged, however, that not all landscapes are green nor outdoors. Illustrating his expansive definition of the subject, Dober considered hardscapes and interior gardens to be important elements of campus landscapes. The book's purpose was to enjoin an “amplitude and appreciation” of campus landscape, because “a campus with minimal landscape is incomplete, inchoate, and incapacitated” (xviii). Dober delineated thirteen campus landscape design determinants which informed the thirty components of his campus design taxonomy. The former are contextual factors that are to be considered in the design of the spatial, graphic, and landscape

types encompassed by the latter (figure 4). Being the functionalist designer that he was, Dober affirmed that the taxonomy is “pragmatic, not theoretical” (xxi). The entire book examined every one of these elements. Curiously, only at the end of the taxonomy, introducing a discussion of wayfinding, lighting, and site furniture, is placemarking discussed, and very briefly so.

So central is the pastoral character of the university campus that the word *campus* had by then come to be applied to non-academic settings characterized by the marriage of architecture and landscape (Mozingo 2003, 2011, Kerr et al. 2016, Collins 1979, Rice 1988, Haresign 1999, Leonard 1999). Despite the increasing popularity and diffusion of the model, Dober described campus landscape “as an endangered art form deserving care, conservation, and curatorial interpretation and assistance” (xxv). Even if campus landscape architecture is a worthy artistic enterprise that has not been given its academic due, this neglect provides an opportunity for intervention. Landscape is “nature's equivalent of a great painting,” and “what nature cannot provide, occasionally designers can invent” (xxv-23). With Dober's attention squarely on landscape, deep in the book was his most succinct definition of campus: “Campus spaces are essentially determined landscape designs” (155). For him, as for Robert Stern, the campus is a purposive pastoral endeavor (Stern 1986, 2010). It is imperative that every campus planning and design project give landscape its due consideration (and, critically, funding). Dober's book was intended to ensure that these efforts and funds are put to good use; it was another of his self-described practitioner's handbooks, a “call for action and demonstration” of the subject's importance and relevance (xxvi). As Dober conceptualized it, campus landscape architecture demands the diligence of the fabricator coupled with the finesse of the painter.

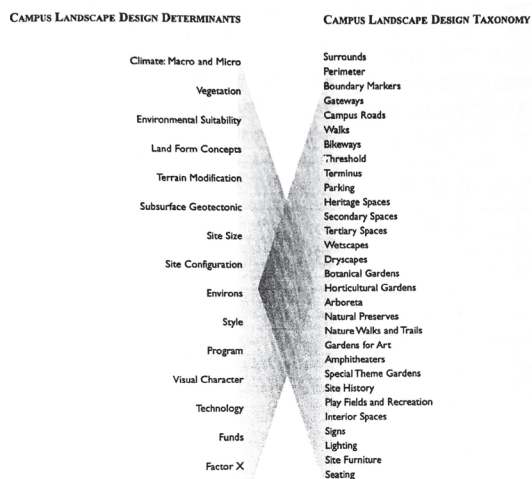


Figure 4: Impact diagram in which the components are impacted by determinants. (Dober 2000, xxi)

2.3. CAMPUS PATRIMONY, CODA OF THE CAMPUS PATRIARCH

The lyricism of the campus building enterprise had at this point risen to the surface of Dober's work. His next three books, his last, *Campus Heritage*, *Old Main*, and *Campus Image and Identity*, focused squarely on campus character and feel. They were published by the Society for College and University Planning, a professional association Dober helped found in 1965. Foregrounding the campus as a purposive human creation at the intersection of art and history, these books constituted his oeuvre's peroratory denouement, crystallizing in printed form Dober's love of campus. Published in 2005 and 2006 respectively, the first two books were companion publications which explored the campus as a repository of history and memory, as

a living museum. Dober defined campus heritage as “the three-dimensional commemoration, celebration, and memorializing of people, activities, and events through and with physical objects that are consciously created or identified to serve and symbolize a college or university’s purpose, presence, and patrimony” (Dober 2005, 5). Seeking to convey the different means through which universities can make their settings more humane and relatable to people in and around them, Dober structured the book as a “descriptive taxonomy of opportunit[ies] for inscribing heritage on campus]: architecture, landscapes, memorials, and naming protocols—the self-evident as well as the idiosyncratic.” (7). Illustrated with material from his personal collection—archival images acquired and photographs taken over the span of half a century—the book is a document of the extent of Dober’s travels, interests, and expertise.

Old Main expanded an eponymous section from *Campus Heritage*’s discussion of historic architecture on campus into an “architectural biography” of a ubiquitous American campus building type (Dober 2006, 15). Based on extensive research, the book strung together brief histories of Main buildings on over 200 campuses, presented alongside archival imagery composed exclusively of historical postcards, to paint a picture of an enduring architectural-academic presence across space and time. This “visually delightful collection of historic picture post cards,” Dober explained, “help[s] support the premise that a rounded view of America’s collegiate enterprises would be incomplete without understanding and acknowledging the contributions these magnificent masterworks have made to campus development” (1).

These books eschewed analytical density for narrative breadth and disquisitive text for expressive imagery. This focus on the image and experience of campus was at home with the 21st-century understanding of campuses as brandscapes (Chapman 2006; Mitchell 2007; Coulson 2010; Silverman and Sweeney 2016). The attention here is less on the causal relationship between environmental design and human behavior than it is on the correlation between campus imageability and complexity on one hand and attraction and belonging on the other. Dober appears to have taken this mantra of evocation over substance to heart; his two penultimate books gave almost equal weight to text and image, but the latter reigned supreme in his final publication. Published two years before his death, his last book was less a scholarly exposition than a brimming coffee table book. It explored the ways in which the material composition that produces the campus sense of place, campus *identity*, can live up to the imaginaries that people construct around specific academic institutions, campus *image* (Dober 2012, 7).

The book commenced with a brief introduction which led into over 400 color photographs, most of which were from Dober’s personal collection. The book was a leisurely photographic survey of campus architecture, art, artefacts, landscaping, and open space design—a travelogue documenting countless instances of what he had two decades earlier termed campus placemaking and placemarking. With this ode to the campus pride of place, Dober bade the discourse a fond adieu.

CONCLUSION

Dober’s intellectual biography is uniquely intertwined with the biography of campus discourse. “It is not often,” Alex Krieger once said, “when someone, virtually single-handedly, reinvents a particular discipline, as Richard Dober certainly did with modern campus planning” (Lehman, Reen, McNamara n.d.). Yet, Dober was not simply akin to a wind driving a discursive flock of birds, but was more like the eldest, largest bird in this growing flock, a bird which had outsize influence on its movements, but which was nonetheless subject to the flock’s collective dynamic. Dober jumpstarted the discourse with his 1960s’ campus planning guide, a book demonstrative of the modernist functionalist approach to campus planning. Here, the design of university grounds was understood as a problem that may be analyzed and broken down into constituent parts, which are then systematically addressed and reassembled. This was simply the beginning for Dober, who spent the rest of his career practicing and writing about campus planning and design. His oeuvre exemplifies the fact that the campus necessarily engages more than a single discipline or profession; at minimum, planning, architecture, and landscape architecture are integral components of campus development. With eight books published on various aspects of the subject, he is the field’s most prolific author.

On the other hand, the most famous campus text, the field’s classic, is Turner’s *Campus*, the first comprehensive history of American campus design. The publication of this monograph was a turning point in the discourse; the determination to tackle the challenges of campus planning and make the best of campus development opportunities gave way to the critical appreciation of campuses as purposive designs. The instrumental study of campus as a functional object took a back seat to the humanistic study of campus as an aesthetic object. Dober’s and Turner’s two books are emblematic of the divide between architecture the profession and architecture the discipline: Dober’s is a handbook for a planning practice, while Turner’s study is an academic history of the campus in the United States. The post-Turner discursive landscape saw the proliferation of publications scrutinizing the campus

as a value-laden object and a spatial inscription of its particular time and place (Stern 1986; Gaines 1991; Muthesius 2000; Kenney et al. 2005; Chapman 2006; Coulson et al. 2010; Stern 2010).

The godfather of the discourse was not immune to this discursive shift; Dober did not resist the humanistic turn. Rather, he took it in stride, producing book after book attempting to reconcile his rationalist, modernist predilections with the ascendance of lyricism and beauty as core analytical concerns. His oeuvre developed and expanded, taking up campus history and aesthetics as primary interpretive threads. The ardent

functionalist of yesteryear had to adapt and assume a humanistic outlook in his later years. So, the story of campus discourse appears to be a bipolar story, a climactic before and after: a modern(ist) Gilgamesh survives the Turner initiated flood of aestheticism by transforming into an aesthete-sailor-savant himself. But perhaps these orientations were not so different in the first place; if Peter Eisenman's (1976) claim that functionalism is scarcely any different from humanism holds, then perhaps Dober's smooth transition is evidence that there was not a discursive shift at all.

REFERENCES

- Chapman, M. Perry. 2006. *American Places: In Search of the Twenty-First Century Campus*. Westport, CT: Praeger.
- Collins, Huntly. 1979. "Corporate Campus: Learning Your Way to a Better Job." *Change: The Magazine of Higher Learning* 11, no. 5: 67-68.
- Coulson, Jonathan, Paul Roberts, and Isabelle Taylor. 2010. *University Planning and Architecture: The Search for Perfection*. London: Routledge.
- Crawford, Mark. 2014. "A Century of Campus Planning: Past, Present, and Future." *Facilities Manager* (July/August): 24-28.
- Dober, Richard P. 1963. *Campus Planning*. New York: Reinhold.
- Dober, Richard P. 1965. *The New Campus in Britain: Ideas and Consequences for the United States*. New York: Educational Facilities Laboratory.
- Dober, Richard P. 1992. *Campus Design*. New York: Wiley.
- Dober, Richard P. 1996. *Campus Architecture: Building in the Groves of Academe*. New York: McGraw-Hill.
- Dober, Richard P. 2000. *Campus Landscape: Functions, Forms, Features*. New York: Wiley.
- Dober, Richard P. 2005. *Campus Heritage: An Appreciation of the History & Traditions of College and University Architecture*. Ann Arbor, MI: Society for College and University Planning.
- Dober, Richard P. 2006. *Old Main: Fame, Fate and Contributions to Campus Planning and Design*. Ann Arbor, MI: Society for College and University Planning.
- Dober, Richard P. 2012. *Campus Image and Identity*. Ann Arbor, MI: Society for College and University Planning.
- Dober, Richard P. n.d. Curriculum Vitae. Belmont, MA: Dober Lidsky Mathey. http://www.dlmlplanners.com/pdfs/DLM_RPD_Resume.pdf
- Eisenman, Peter. 1976. "Post-Functionalism." *Oppositions* 6 (Fall): 9-12.
- Gaines, Thomas A. 1991. *The Campus as a Work of Art*. New York: Praeger.
- Haresign, David T. 1999. "Is a Corporate Campus Right for Your Business?" *Site Selection* 44, no. 1 (January): 1118-20.
- Kanvinde, Achyut, and H. James Miller. 1969. *Campus Design in India: Experience of a Developing Nation*. Topeka, KS: Jostens/American Yearbook Co.
- Kenney, Daniel R., Ricardo Dumont, and Ginger Kenney. 2005. *Mission and Place: Strengthening Learning and Community Through Campus Design*. Westport, CT: Praeger Publishers.
- Kerr, Clark. 2001. *The Uses of the University*. 5th ed. Cambridge: Harvard University Press.
- Kerr, Ron, Sarah Robinson, and Carole Elliott. 2016. "Modernism, Postmodernism, and Corporate Power: Historicizing the Architectural Typology of the Corporate Campus." *Management & Organizational History* 11, no. 2: 123-146.
- Lehman, Reen, McNamara Funeral Home. 2014. "Richard P. Dober: March 30, 1928 ~ January 21, 2014 (age 85)." Obituary. <https://www.lehmanreen.com/notices/Richard-Dober>
- Leonard, Sharon. 1999. "Is a Corporate Campus in Your Future?" *HRMagazine* 44, no. 10 (January): 215.
- Lynch, Kevin. 1960. *The Image of the City*. Cambridge: MIT Press.
- Mitchell, William J. 2007. *Imagining MIT: Designing a Campus for the Twenty-first Century*. Cambridge: MIT Press.
- Mozingo, Louise. 2003. "Campus, Estate, and Park: Lawn Culture Comes to the Corporation" in *Everyday America: Cultural Landscape Studies after J. B. Jackson*. Edited by Chris Wilson and Paul Groth. Berkeley, CA: University of California Press.
- Mozingo, Louise. 2011. *Pastoral Capitalism: A History of Suburban Corporate Landscapes*. Cambridge: MIT Press.

A Campus Biography

- Muthesius, Stefan. 2000. *The Postwar University: Utopianist Campus and College*. New Haven, CT: Yale University Press.
- Rice, A. Franklin. 1988. "Creating a Corporate Campus: A Site Feasibility Study." Masters thesis, Massachusetts Institute of Technology. <https://dspace.mit.edu/handle/1721.1/14618>
- Saarienen, Eero. 1960. "Campus Planning: The Unique World of the University." *Architectural Record* 128 (November): 123-130.
- Schmertz, Mildred F. 1972. *Campus Planning and Design*. New York: McGraw-Hill.
- Silverman, Jonathan, and Meghan Sweeney, eds. 2016. *Remaking the American College Campus: Essays*. Jefferson, NC: McFarland & Company.
- Stern, Robert A. M. 1986. "Academical Villages: A Place a part," *Pride of Place*. PBS teleseries. Directed by Murray Grigor. Published in VHS format by Films for the Humanities, Princeton, NJ.
- Stern, Robert A. M. 2010. *On Campus: Architecture, Identity, and Community*. Edited by Peter Morris Dixon, Alexander Newman-Wise, and Jonathan Grzywacz. New York: Monacelli Press.
- Turner, Paul Venable. 1984. *Campus: An American Planning Tradition*. New York: Architectural History Foundation.
- UNESCO. 1975. *Planning Buildings and Facilities for Higher Education*. Stroudsburg, PA: Dowden, Hutchinson & Ross.
- UNESCO. 1979. *Planning Standards for Higher Education Facilities: Examples from National Practice*. Paris: UNESCO.

RIVAL GEOGRAPHIES: Race-Relations, Power, and National Planning In Postwar America

Shahab Albahar
University of Virginia

Abstract: The following article is a critical, historical study of national planning interventions in the United States between 1945 and 1964. Drawing from race-radical scholarship, it reinterprets the national urban renewal movement at the end of WWII as a *racial project* that exercised a 'color-blind' rhetoric to legitimate the expansion of government police powers and help pave the way for the spatial specifics of global neoliberalism. It uses the case of Southwest Washington, DC, to explore the intersection of social identity, the law, and spatial policy during the early Cold War years. It views planning as a settler colonialist project, subservient to dominant systems through sustained *racialization*. It analyzes modernist planning at the nexus of state-society-space power relations to elucidate the dialectic of 'planning as social oppression.' By critically examining the landmark decision in *Berman*, I conceive planning as mediating the "social production of space" at the disjuncture of legal interpretation and urban transformation. I speculate that court legitimations of overtly racist urban policies are reflective of an epistemic lag between the American judicial branch and rapidly shifting discourses on urban development. Using a historical-materialist lens Jodi Melamed reinterprets U.S. literary studies as a "key site of geopolitical struggle around the meaning and significance of race" (Melamed 2011, xv) and goes on to argue the entrance of *official antiracisms* into American governmentality at the end of WWII and the new world-historical formation that ensued was conducive for U.S. global ascendancy and leadership of transnational capitalism. In her developed genealogy of "race-liberal orders", Melamed distinguishes three successive antiracist regimes. By linking the first antiracist regime, "racial-liberalism" (1945-1964) with the national urban renewal movement, this essay critiques institutionalized planning praxis through the lens of antiracisms. I argue that national planning efforts constituted a form of *antiracist negating mechanisms*. Whereas official antiracisms engaged the discursive spaces of the public sphere by explicitly locating race "as the central problem – the crux of everything wrong and unequal in governance, economy, and society," (Melamed 2011, x) *antiracist negating mechanisms* endorsed a 'color-blind' rhetoric to further obscure the workings of heteronormative hegemony in physical space. Therefore, I do not conceive *antiracist negating mechanisms* dialectically as antithetical to official antiracisms; rather they function in synergetic complementarity. In an effort to illuminate the silencing discourses in modernist planning projects, I conclude by proposing a queer-of-color framework towards advancing a *critical planning theory*.

Keywords: Washington, D.C., antiracisms, urban renewal, eminent domain, racial planning

INTRODUCTION

The following essay is a critical, historical analysis of national planning interventions in the United States between 1945 and 1964. Drawing on arguments made by race-radical scholars, it reinterprets the national urban renewal movement at the end of WWII as a *racial project* that exercised a 'color-blind' rhetoric to help expand government police powers and help realize the spatial specifics of neoliberal dominance. It uses the case of Southwest Washington, DC, to explore the intersection of social identity, the law, and spatial policy during the early Cold War years. It views institutionalized planning as a settler colonialist project that works to maintain heteronormative hegemony through sustained "racialization" processes. It analyzes modernist planning at the nexus of state-society-space power relations to elucidate the dialectic of "planning as social oppression" (Yiftachel 1998). By critically examining the 1954

landmark decision in *Berman v. Parker*, I conceive of planning as mediating the "social production of space" (Lefebvre 1991) at the disjuncture of legal interpretation and urban transformation. I speculate that court legitimations of overtly racist planning projects are reflective of an epistemic lag between orthodoxy in the American judiciary and the rapidly shifting sociocultural discourses on urban development. Using a historical-materialist lens, Jodi Melamed reinterprets U.S. literary studies as a "key site of geopolitical struggle around the meaning and significance of race" (Melamed 2011, xv). In *Represent and Destroy*, Melamed concludes that the entrance of *official antiracisms* into American governmentality in the WWII "racial break" and the new world-historical formation that ensued was conducive for U.S. global ascendancy and leadership of transnational capitalism. In her developed genealogy,

she identifies three successive *official antiracist regimes* pertinent to the historical evolution of institutionalized planning in the United States: “racial-liberalism (1945-1964); liberal-multiculturalism (1965-1990s); and neoliberal-multiculturalism (2000s).” (Melamed 2011, 1) By linking the first official antiracist regime, racial-liberalism, to the national urban renewal movement, the 1945 District of Columbia Redevelopment Act (DCRA) arguably paved the way for what I am coining as *antiracist negating mechanisms*. Whereas official antiracisms engaged the discursive spaces of the public sphere by explicitly locating race “as the central problem – the crux of everything wrong and unequal in governance, economy, and society,” (Melamed 2011, x) antiracist negating mechanisms endorsed a ‘color-blind’ rhetoric to further obscure the workings of heteronormative hegemony in physical space. Therefore, in my formulation *antiracist negating mechanisms* are not negations of official antiracisms; rather they dually function in synergetic complementarity. In *Chocolate City*, co-authors Chris Asch and George Musgrove argue for “race above all other cultural distinctions” (Asch and Musgrove 2017, 3) as the principle factor for all sociospatial divides and inequalities endemic in Washington, D.C., today. They write:

While it may be a social and historical construction...it is also a powerful lived reality that has influenced how (and where) Washingtonians of all races have lived, worked, voted, and interacted (Asch and Musgrove 2017, 3).

In an effort to illuminate the silencing violences in modernist planning praxis, I turn to the work of Roderick Ferguson in the conclusion to reflect on the usefulness of queer-of-color analyses for invoking a critical planning theory (Gunder 2011).

1. REPRESENT AND DESTROY

1.1. *BERMAN V. PARKER*, 348 U.S. 26 (1954).

Professions (like nations) keep their shape by molding their members’ (citizens’) understanding of the past, causing them to forget those events that do not accord with a righteous image, while keeping alive those memories that do. (Sandercock 1998, 1)

Berman is a landmark decision of the U.S. Supreme Court that reinterpreted the Takings Clause¹ of the Fifth Amendment to the U.S. Constitution and set the precedent for our modern-day eminent domain jurisprudence. In the early twentieth-century, Max Morris, a free black Washingtonian, lived and worked in Southwest, DC. For over twenty-five years, Mr. Morris ran a profitable business, Frank’s Department Store, in the commercial hub of Southwest, located on 4 ½ Street (figure 1). Then, in 1952, Mr. Morris received final notice of property acquisition by the Redevelopment

Land Agency (RLA), forcing his business shut. Mr. Morris challenged the constitutionality of the RLA on the grounds that its use of eminent domain power violates the Takings Clause of the Fifth Amendment, which prohibits the taking of “private property for public use without just compensation” (U.S. Const. art. I, § 8, cl. 5.). Prior to *Berman*, the Supreme Court maintained a narrowed interpretation of the “public use” consistent with ‘actual-use’ theory, which permits the taking of private property only when necessary for use by the entire public without exemption—a highway for example—or for uses by the government acting on behalf of the public as its representative, as in the instance of a military base. In *Berman*, the Court expanded its interpretation of the “public use” more broadly to include “public purpose.” Justice William O. Douglas, who delivered the majority opinion wrote:

Subject to specific constitutional limitations, when the legislature has spoken, the *public interest* has been declared... In such cases, the legislature, not the judiciary, is the main guardian of the public needs to be served by social legislation, whether it be Congress legislating concerning the District of Columbia or the States legislating concerning local affairs...Public safety, public health, morality, peace and quiet, law and order—these are some of the more conspicuous examples of the traditional application of the police power to municipal affairs. Yet they merely illustrate the scope of the power, and do not delimit it...*Miserable and disreputable housing conditions may do more than spread disease and crime and immorality*. They may also suffocate the spirit by reducing the people who live there to the status of cattle... *If those who govern* the District of Columbia decide that the Nation’s Capital should be beautiful as well as sanitary, there is nothing in the Fifth Amendment that stands in the way. Once the object is within the authority of Congress, the right to realize it through the exercise of eminent domain is clear... The entire area needed redesigning so that a balanced, integrated plan could be developed for the region, including not only new homes, but also schools, churches, parks, streets, and shopping centers... Once the question of the *public purpose* has been decided, the amount and character of land to be taken for the project and the need for a particular tract to complete the integrated plan rests in the discretion of the legislative branch...The rights of these property owners are satisfied when they receive that just compensation which the Fifth Amendment exacts as the price of the taking. (*Berman v. Parker*, 348 U.S. 26 1954)

In its more contemporaneous application of ‘regulatory takings,’ the Court reinterpreted the Public Use Clause in accordance with ‘public-benefit’ theory, which, when broadly construed, induces greater ambiguity. Consequentially, this semantic shift sparked much controversial debate concerning the limits of government powers and their respective infringements on individual freedoms. A taking generated for a direct ‘public-benefit’ eliminates the necessity for ‘actual-use,’ while further justifying the expansion of government

police powers under the rubric of serving the “public purpose” or “interest.” By mid-twentieth-century, the elimination of “urban blight” constituted a substantive ‘public interest.’ The national urban renewal movement played a central role in the demise of the Public Use Clause where judicial deference to local legislatures engendered the abuse of eminent domain powers in such instances where real properties were seized from marginalized social groups and ownership titles transferred to the hands of social elites. Between 1955 and 1966, urban renewal programs displaced well over 300,000 families across the U.S., and the burden fell disproportionately on African Americans and communities of color whose neighborhoods were frequently targeted for large-scale redevelopment plans. Since its inception, black activists denounced the racist agendas of urban renewal programs, albeit dissenting political action was mostly circumscribed within localized efforts, such as concerted street protests. In the early 1960s American novelist James Baldwin infamously dubbed urban renewal as “Negro Removal.” Nonetheless, the woes of afflicted black communities were largely neglected in dominant society, and the courts were mostly unsympathetic towards their legal pursuits for justice.

To raise the question of how a “formally liberal capitalist-state” (Melamed 2011, x) is capable of legitimating prolonged discriminatory violences against racialized minorities, as evinced in the diasporic effects of urban renewal on African American communities, invokes a critical interrogation of the dialectic of planning as part of the disciplining instruments of the “carceral” modern state (Foucault 1977, 297). Several sociopolitical forces converged at the end of WWII to realize the wholesale clearance of majority black

neighborhoods vis-à-vis urban renewal programs. According to Melamed, prior to WWII, white supremacy justified economic inequality within the United States and Europe and between colonizers and their colonies. Starting from the end of WWII and culminating in the 1960s, many challenges to old forms of racial hierarchy, including anticolonialist movements, a worldwide rejection of fascism, and the ideological rivalries between a capitalist order of nation-states led by the U.S. and International Socialism led by the U.S.S.R., converged to constitute what sociologist Howard Winant refers to as a “racial break” (Melamed 2011, ix). The post-WWII “racial break” registered a global shift in the worldwide racial system that had endured for centuries (Winant 2001), which brought white supremacist modernity on the cusp of permanent crisis, and linked official antiracisms in the U.S. to “democratic political development” more strongly than ever before. Melamed observes:

After the racial break state-recognized U.S. antiracisms replaced white supremacy as the chief ideological mode for making the inequalities that global capitalism generated appear necessary, natural, or fair. (Melamed 2011, xvi).

Meanwhile, the mass dissemination of race knowledges and the subsumption of black cultural productions in mainstream literary studies instituted a novel form of normalizing and rationalizing violence. This new violence was more powerful than ever before, because as liberal categories of racial difference assumed the dominant mode for securing institutionalized knowledges, categories of difference were used to analyze and explain economic inequalities, as opposed to the workings of “differential value that sort humanity into various designations of value and valuelessness” (Melamed 2011, xiii-xiv). Consequently, the epistemological disjuncture between a politics of “misrecognition” and a politics of “maldistribution”² (Fraser 1998) and the subsequent fracturing in the Left provided the desirable conditions for a liberal-capitalist modernity to ascertain hegemony by further dissociating cultural categorizations from economic disparities.

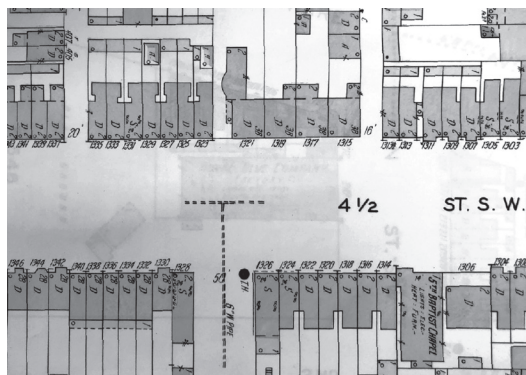


Figure 1: Sanborn Fire Insurance map of Four-and-a-Half Street, SW from 1888. The map illustrates a street flanked by buildings filling up the plot divisions. The pink color represents structures built from brick and the plan itself portrays an orderly layout of buildings reflective of a commercial street today. (Library of Congress 1888)

1.2. SPACE-SPHERE DIALECTIC

Public space often, though not always, originates as a representation of space...But as people use these spaces, they also become representational spaces, appropriated in use. Public space is thus socially produced through its use as a public space. (Mitchell 2003, 129)

In their “racial formation” theory, Omi and Winant challenge essentialist notions of race, viewing it instead as a dynamic and fluid social construct, wherein racial categories are “created, inhabited, transformed, and destroyed” by ongoing sociohistorical processes

(Winant and Omi 1994, 55). *Racialization* signifies the processes that ascribe 'racial categories' to a relationship, social practice, or group that did not identify itself as such, akin to what cultural critic Edward Said formerly implied as *Othering* – the dehumanizing and demonizing processes by which a hegemonic group claims moral superiority over a subordinated group (Said 1978). In this respect, "racial projects" represent those historically specific social, political, and cultural technologies that shape or direct the process of racialization. Racial projects operate at two fundamental levels: at the micro-level they interpret, represent or explain the meaning of particular racial dynamics; and at the macro-level they reorganize and redistribute resources on the basis of race (Winant and Omi 1994, 56). Accounting for the materialist implications of racialization, Melamed's work illuminates the dialectical tension inherent between a 'politics of recognition' and a 'politics of distribution.' The *Berman* case, decided just six months after the Supreme Court ruling in *Brown v. Board of Education*, which outlawed racial segregation in public schools, attests to this notion that official antiracisms implying racial-liberalism in the 'public sphere,' collude with *antiracist negating mechanisms* implying technological progress in the 'spatial sphere' in order to realize a racial project. I call this the *space-sphere dialectic*. In the *space-sphere dialectic of racial-liberalism* (1945-1964), "the massive production and dissemination of representations of black experience formulated in accord with the rubric of the Negro problem" performed the micro-level operations of a racial project (Melamed 2011, x). Meanwhile, at the macro-level, renewal advocates turned to various "scientific" knowledges in their campaigns towards constructing a newly reconfigured dominant ideology for understanding the urban. By appropriating "technical" terminology, such as "blight" and "obsolescence," used in discourses in agriculture and economics respectively, proponents for urban renewal forged a new language that helped recast urban decline as an existential threat to national security and an urgent matter that only be overcome in the reorganizing and redistributing principles of large-scale redevelopment schemes.

By early 1955, Frank's Department Store and neighboring Schneider's Hardware Store were among the 4,800 structures razed in Southwest. Spanning a twenty-year period, the urban renewal of Southwest displaced approximately 1,500 businesses and 23,000 residents (almost 6,000 families), from 560-acres of land that had formerly been occupied by the largest concentration of African American residents in Washington, DC. Data gathered from decennial surveys conducted in 1950 and 1970 reveal the drastic transformation of Southwest's racial composition at

the completion of urban renewal. Between 1950 and 1970, the black population in the Southwest urban renewal area plunged from 69% to 32%. Meanwhile, DC, experienced an inverse demographic shift during the same time period with black residents constituting 71% of the total population in 1970 compared with 35% in 1950, earning the nation's capital its epithet "Chocolate City." The landmark ruling in *Berman* laid the foundation for much of our modern-day eminent domain jurisprudence, and the U.S. government arguably rendered Southwest, DC, 'ground zero' in the postwar urban renewal movement. More than 800 cities applied for federal aid in urban renewal programs and a succession of similar violences were launched against racialized neighborhoods, including but not limited to Boston's West End, Los Angeles' Bunker Hill, Detroit's Poletown, and Charlottesville's Vinegar Hill. Although renewal programs mandated that redevelopment plans provide substitute accommodations for those displaced, enforcement policies were feeble and as early as 1956 public housing projects were quickly abandoned in favor of profitable capitalist ventures that would attract the suburbanite middle-classes back to the inner cities, reconfigured as spaces for consumption. Over the course of two decades, the communities of Southwest gradually disappeared at a cost of \$500 million (equivalent in value to \$4.6 billion today).

1.3. THE SOUTHWEST "PROBLEM AREA"

Published in 1950, the first comprehensive plan proposed for Washington, DC, identified Southwest as a "problem area" suffering from urban "blight," therefore in need of redevelopment (NCPPC). At the end of 1952, with the passage of the first urban renewal plan for a Southwest Project Area B,³ urban renewal moved from the planning stage to the action stage, sparking a wave of racial dramas in cities across the American landscape. Located in the 700-block area of 4½ Street SW, Frank's Department Store was well within the 76-acre boundary of Project Area B. Faced with the prospect of losing his business Mr. Morris and neighboring business owner Goldie Schneider refused to sell to the RLA. To stop the government from condemning their properties through eminent domain, Mr. Morris and Mrs. Schneider filed suit in federal district court, challenging the constitutionality of the DCRA. They argued the government's ability and scope to take and transfer private property to private developers, as part of a project to eliminate "blight," does not constitute a legitimate "public use." Rather, the taking of private property from one business owner for the benefit of another business owner under eminent domain amounts to an unconstitutional taking, thus violating the Public Use Clause of the Fifth Amendment

to the U.S. Constitution. Contending their businesses were not “blighted” (figure 2), the claimants further argued that since the DCRA had not defined the term “blight,” the RLA could not apply this ambiguous term to all of Project Area B. That said, however, the circuit court dismissed their allegations and the case was appealed to the U.S. Supreme Court, which upheld the decision and reaffirmed the constitutionality of the DCRA. The conflict between Morris, Schneider, and the RLA highlights a critical tension in American jurisprudence within the political economy of the early Cold War: the struggle to balance an image of the U.S. nation-state as a formally liberal-capitalist modernity against rationalizations for persistent distributive inequalities along racial divides. It also illuminates an epistemic lag between the American judicial system and shifting sociocultural discourses on urban development. The next chapter uses the *Berman* case as an example to further illustrate this epistemic lag between the courts’ interpretation of the law and urban transformation.



Figure 2: The 700 block of 4th Street, where Max Morris’ department store and Goldie Schneider’s hardware store were located prior to redevelopment. (Lavine 2010, 452).

2. PLANNING AS RACIALIZATION FOR THE CARCERAL MODERN STATE

2.1. ENGINEERING SOCIAL BELIEF

By late-nineteenth century, the outcomes of industrial capitalism on cities have already come to be characterized by stark inequalities. Marx’s notion of alienation,⁴ limited in his totalizing assumptions on heteropatriarchy, is challenged by empirical accounts documenting “slumming vogues” (Heap 2009). According to American historian Chad Heap, the emergence of slumming as a new form of urban amusement in the mid-1880s, helped portions of the urban populations in places like Chicago and New

York negotiate concurrent shifts in heterosexuality, homosexuality, whiteness, and blackness (Heap 2009). By “slumming,” Heap refers to the physical act of transgression, typically performed by a bourgeois body who consciously violates sociospatial divides, for the purposes of touring the urban enclave of an inferior social group. The scholar convincingly charts how a succession of slumming vogues responded to alterations in sexual, racial, and socioeconomic classification and helped constitute novel identity formations and categorizations. But slumming excursions provided more than simply spaces for entertainment and cultural diffusion, as they also contributed to the development of restrictive social policies in the early twentieth century, culminating in the Volstead Act of 1919, formally known as the Eighteenth Amendment, which ushered in the Prohibition Era. As a precursor to modern-day surveillance and policing, slumming excursions helped Progressives maintain cultural hegemony through the concurrent sociologization and statistical interpretation of sexual and racial knowledges. Foucault argued that the emergence of the category “population” represented “one of the great innovations in the technique of power in the eighteenth century” (Foucault 1990, 25). Based on his understanding of population, Foucault writes:

Governments perceived that they were not dealing with subjects, or even with a “people,” but with a “population,” with its specific phenomena and its peculiar variables: birth and death rates, life expectancy, fertility, state of health, frequency of illnesses, patterns of diet and habitation At the heart of the economic and political problem of population was sex: it was necessary to analyze the birthrate, the age of marriage, the legitimate and illegitimate births, the precocity and frequency of sexual relations, the ways of making them fertile or sterile, the effects of unmarried life or of those prohibitions, the impact of contraceptive practices . . . (Foucault 1990, 25-6).

Roderick Ferguson revises Foucault’s theory beyond Eurocentric presumptions by locating the origins of heteronormative values concurrently in the endemic negations and subversions of black cultural formations:

in the context of racial knowledge about African Americans, statistics was a way of gleaning sexual truths about that group. Statistics helped to present African Americans as a population for study and evaluation. The methodologies therein could help illuminate the gendered and sexual peculiarities of African American existence. Statistics helped to produce surveillance as one mode, alongside confession, for producing the truth of sexuality in Western society. As sex was “sociologized,” surveillance helped to constitute sexual knowledge in this way: sociological knowledge would be produced for the good of social order. With this effort in mind, canonical sociology would help transform observation into an epistemological and “objective” technique for the good of the modern state power. (Ferguson 2004, 77).

At the core of his argument, Ferguson implies an inseparability between queer identities and racial formations. According to the scholar, queerness and blackness are mutually constituted categories, manifested through "othering" assemblages. Said differently, in the concurrent racialization and sexualization of non-white bodies, blackness is endemically pathologized and conceived as antithetical to heteronormative respectability. As such, deviations from established hegemonic ideals are weighted against a black/white dichotomy, which forms the basis for differentiated valuation and devaluation. Ferguson opens the introduction of his text, *Aberrations in Black*, with a scene from Marlon Riggs' *Tongues United*, postulating the black drag-queen prostitute an affirmation of the innate perversity of urban capitalism:

Figures like her, ones that allegedly represent the socially disorganizing effects of capital, play a powerful part in past and contemporary interpretations of political economy. (Ferguson 2004, 1).

The politicization of aesthetics in the closing decades of the nineteenth-century proved to be a powerful discursive tool for Progressives who sought to eliminate the perceived social dangers engendered by industrial capitalism in the wholesale clearance and ordered reconfiguration of urban space. As Ferguson states:

Postulating sexuality as a general and diffuse causality provides an example of how sexuality came to mean much more than eros, "sexual instincts", and practices, but came to signify a host of apparently "nonsexual" factors. (Ferguson 2004, 77).

In the latter part of the nineteenth-century, representations of poor people and their neighborhoods were complemented with the emergence of visual sociology. The integration of documentary photography in sociological research developed a knowledge system premised on the belief that photographs could not lie and that cameras captured reality and presented subjects in a truthful manner (Chronopoulos 2014, 209). For social scientists seeking force-causing claims to theorize social phenomena, housing and neighborhood conditions, illiteracy and poverty became omens of gender and sexual pathologies that could topple the rational order of cities and even the nation (Ferguson 2004, 77).

The close proximity of Southwest to the Monumental Core,⁵ and social angst relating to its slum-like condition rendered it a prime site for testing the efficacy of urban renewal. RLA surveyors evaluated housing conditions in Southwest based solely on exterior inspection. Despite the inherently subjective methodology involved when appraising aesthetics, in codifying their observations according to a predetermined set of classifications, authorities presented their findings in statistical form and claimed

their study as objectional truth. In their survey, they determined that, of the 3,370 buildings in the area, only 4% were in good condition, while 40% were obsolescent and 56% were "blighted," providing reformers with some of the most poignant statistics for the purposes of making a case for renewal (*RLA Annual Report* 1951, 9). Title I of the *Housing Act* of 1949 provided subsidies for the clearance of areas designated as slums, so that private developers could rebuild them (Chronopoulos 2014, 207). Between 1949 and 1960, chairman of the Mayor's *Committee on Slum Clearance*, Robert Moses planned 35 urban renewal projects in New York City alone, realizing half, and receiving \$65.8 million in Title I funds. An advocate of modernization and a pioneer planner in the early urban renewal era, Moses exploited the symbolic and interpretive qualities of photography to lead the largest slum clearance program in the U.S. during the '50s. To this end, the *Committee on Slum Clearance* published a brochure for every renewal proposal (Chronopoulos 2014), that:

arranged statistics, graphics, maps, photographs and illustrations in highly sophisticated ways to construct a powerful visual argument for the demonstration of blight. (Zipp 2010, 223).

Economist Mabel Walker defines a "blighted area" as:

an area in which deteriorating forces have obviously reduced economic and social values to such a degree that widespread rehabilitation is necessary to forestall the development of an actual slum condition. (Chronopoulos 2014, 210).

During the Great Depression, the term "blight" was elevated and joined the term slum. Beginning in the 1930s, both terms were used interchangeably to explain urban decline and advocate various forms of rehabilitation.

2.2. THE SPATIAL PRODUCTION OF LAW

The division of powers between the federal government and the states, provided in the Tenth Amendment to the U.S. Constitution, grants local governments legislative authority to formulate and enact zoning laws and landuse controls as they deem necessary for establishing and securing orderly urban spaces. The legitimacy of modern planning praxis is premised on the ideological belief that landuse zoning and building regulations are crucial for the mutual protection of private properties and the general welfare of the public, such as health, safety, peace, law and order (Sutton 2008, 7). To this end, planning commissions are empowered with legislative autonomy to decide on local affairs by virtue of judicial deference, albeit constricted within constitutional bounds. Justice Douglas affirms this notion when deliberating the majority opinion in the *Berman* case:

Subject to specific constitutional limitations, when the legislature has spoken, the public interest has been declared... In such cases, the legislature, not the judiciary, is the main guardian of the public needs to be served by social legislation...Public safety, public health, morality, peace and quiet, law and order—these are some of the more conspicuous examples of the traditional application of the police power to municipal affairs. Yet they merely illustrate the scope of the power, and do not delimit it. (*Berman v. Parker*, 348 U.S. 26 1954)

The legal basis for planning and zoning in the U.S. was laid by two Standard Enabling Acts published by the U.S. Chamber of Commerce in the 1920s (*American Planning Association*). In 1921, Commerce Secretary, Herbert Hoover appointed an advisory committee to draft the Standard Enabling Acts. After several revisions, the Government Printing Office published the first Act in 1924, a Standard State Zoning Enabling Act (SSEA), followed by a revised version in 1926. Section §1 of the SSEA provided a grant of power—

for the purpose of promoting health, safety, morals, or the general welfare of the community, the legislative body of cities and incorporated villages is hereby empowered to regulate and restrict the height, number of stories, and size of buildings and other structures, the percentage of lot that may be occupied, the size of yards, courts, and other open spaces, the density of population, and the location and use of buildings, structures, and land for trade, industry, residence, or other purposes. (*Standard Zoning Enabling Act, Department of Commerce*, 1926)

The second Act, a Standard City Planning Enabling Act (SCPEA), was published in 1928. The SCPEA covered six subjects, one of which was the “organization and power of the planning commission, which was directed to prepare and adopt a masterplan” (*Standard City Planning Enabling Act, Department of Commerce*, 1928). Most pertinent to these Acts, was their enabling provision, which rendered zoning and landuse regulation within the scope of local police enforcement. Having undergone multiple revisions, the Standard Acts were imbued with controversy from their inception. The question of semantics and the articulation of meaning dominated the debates. Planning consultant and draft reviewer Harland Bartholomew insisted on modifying Section §3 of the SSEA, such that the phrase “such regulations shall be made in accordance with a *well-considered plan*” be replaced with “such regulations shall be made in accordance with a *comprehensive city plan*” (Knack 1996). In an effort to expand police powers even further, Edward M. Bassett left out the more innocuous term “city” from the final publicized version. A “comprehensive plan” as opposed to a “well-considered” plan makes it extremely difficult for lay persons to challenge the constitutionality of eminent domain power in areas designated for urban renewal. Once enacted as public policy, a comprehensive plan

becomes legally binding and the burden shifts to the dissident individual to prove the unconstitutionality of governmental decisions. In areas where isolated properties are not markedly “blighted,” the provisions of a comprehensive plan take precedence over private interests, premised on the logic that spot remedies otherwise referred to as “piecemeal” zoning are to be avoided to promote the general public interest. As such, municipal authorities are empowered, by extension of endorsed comprehensive planning, to condemn private property for the wholesale redevelopment of “blighted” areas, thereby rendering the exercise of eminent domain within the legitimate scope of municipal police powers. The importance of representation in planning discourse cannot be overstated, and the power of language in asserting hegemonic control has been expressly discussed in planning literature. According to planning theorist Michael Gunder, “We act as planners in and through language” (Gunder 2010, 201). Because language mediates the space of communication in the constitution of shared ideology, the formulation of effective public policy is, at best, a complexly iterative process that calls for a critical interrogation of semantics. As Sarah Kay writes:

The space of political universality is one of ideological struggle. For a hegemonic group to establish itself at the expense of others, it needs to colonize this space in its own interests. The political universal is thus usually the exact opposite of what one might take it to be: not an abstraction from a set of particulars, but the manifestation of the express interests of a particular group. (Kay 2003, 151).

The integration of visual imagery with textual documents when constructing narratives aimed at shaping public perceptions on urban policy is the most instrumental method used in planning to attain spatial consensus (Shanken 2018).

CONCLUSION

Michael Frisch posits the “development of modern planning arose at the same time as modern conceptions of sexual orientation” (Frisch 2002, 254). He argues that planning is fundamentally a heterosexist project that privileges reproductive heterosexism in its various theories and practices (Frisch 2002). While he may be right to say that planning promotes heteronormative ideals, this essay aimed at deconstructing a rigid hetero/homo binary maintained in Frisch’s argument by suggesting the rise of modernist planning in the U.S. in the postwar era as fueled by renewed social anxieties rooted in enduring racialization. At the end of the Civil War, the supersession of feudalism by capitalism as the dominant mode of production altered the spatial organization of American society. Rapid urbanization stimulated by industrial capitalism and a laissez-faire

political economy produced surplus populations. Marx defines surplus labor as that labor that capitalist accumulation:

constantly produces, and produces indeed in direct relation with its own energy and extent...always ready for exploitation by capital in the interests of capital's own changing valorization requirements (Marx 1977, 782-4).

In the U.S., racialized groups who have historically been excluded from the rights and privileges of citizenship constituted the surplus populations. In Washington, D.C., surplus populations were concentrated in the Southwest quadrant which provided the geographic context out of which nonheteronormative formations emerged. Responding to the social anxieties provoked by the cross-racial sexual transgressions evinced in the "slumming vogues" that captured the cultural imagination of Americans beginning in the late-nineteenth century, zoning was institutionalized in the early-twentieth century as an effort to bring social order and restore white supremacy through the strict policing of sociospatial boundaries. Conversely, the constriction of marginal populations within tightly regulated urban enclaves incited political mobilization among socially oppressed groups who developed countercultural discourses and practices. In the political climate of the Cold War, communal life was perceived as an existential threat to the ideological dominance of a capitalist-order of nation-states. The new world historical formation in the post-WWII "racial break" prompted the development of a new racial project in U.S. governmentality: its disciplining institutions were, at the micro-level, the entrance of official antiracist discourses in U.S. literary studies, and at the macro-level, the wholesale clearance

of working-class neighborhoods through the urban renewal program under the guise of modernization, and the subsequent reconfiguration of cities to attract the emergent mode of transnational capitalism. Thus, planning helped sustain white supremacy and hegemony in racial projects that effected the total erasure of nonwhite neighborhoods and the permanent dispersal of historically rooted communities, with Southwest DC, providing the ultimate site to test the limits of government powers in what later became 'ground-zero' in the urban renewal movement. Advocating for a critical planning theory, Michael Gunder writes, "we act as planners in and through language" (Gunder 2010, 201). We saw how the emergence of visual sociology at the end of the nineteenth-century and the integration of documentary photography served as a powerful tool for securing cultural hegemony, premised on the belief that photographs captured reality and presented subjects in a truthful manner. The politicization of aesthetics under the auspices of scientific technicality is deeply implicated in courts' interpretations of the law and the subsequent application of discriminatory public policies against oppressed social groups, invoking a "right to the city" discourse.

ACKNOWLEDGMENTS

I thank Professor Kwame Edwin Otu (Assistant Professor at the Carter G. Woodson Institute for African-American and African Studies at the University of Virginia), and my colleague Alissa Ujie Diamond for inspiring me to write this essay and for their immense guidance to relevant literature and their critical feedback on the content of my paper.

ENDNOTES

¹ The Fifth Amendment of the United States Constitution provides a provision widely known as the Takings Clause, which states that "private property shall not be taken for public use, without just compensation." A taking occurs when the government seizes private property. This action is governed by rules set by the legislature.

² The debate between Butler in *New Left Review* and Fraser called attention to the fractured politics of the Left. Butler argues that the struggle against (hetero)sexism is inseparably a struggle against capitalist exploitation. In other words, (hetero)sexism is not merely cultural. Similarly, Fraser rejoins that the analytical distinction between harms of *maldistribution* and *misrecognition* is justified by capitalist society's ability to cleave between the economic sphere as separately from the cultural sphere.

³ Southwest Washington Urban Renewal Area – bounded by Independence Avenue, Washington Avenue, South Capitol Street, Canal Street, P Street, Maine Avenue and Washington Channel, Fourteenth Street, D Street, & Twelfth Street – for more info. refer to *HABS Report by the National Parks Service*.

⁴ The theoretical basis of alienation within the capitalist mode of production is that the worker invariably loses the ability to determine life and destiny when deprived of the right to think (conceive) of themselves as the director of their own actions; to determine the character of said actions; to define relationships with other people; and to own those items of value from goods and services, produced by their own labor. Although the worker is an autonomous, self-realized human being, as an economic entity this worker is directed to goals and diverted to activities that are dictated by the bourgeoisie—who own the means of production—to extract from the worker the maximum amount of surplus value in the course of business competition among industrialists.

⁵ The Monumental Core – "The Mall, with its long sweep of green from the Capitol to the Potomac and from the White House to the Jefferson Memorial, should be treated with exceptional sensitivity to the values inherent in its formal composition. Attempts to "protect, complete, enhance, and humanize" should proceed in the full knowledge that the Mall as it exists is a unique space, albeit a space with problems" in *Proposed Physical Development Policies for Washington, D.C. 1965-1985*. NCPD.

REFERENCES

- Altshuler, A. 1965. "The Goals of Comprehensive Planning." *The Journal of the American Institute of Planners* Vol. 31, No. 3: 186-195.
- Ammon, F. 2009. "Commemoration Amid Criticism: The Mixed Legacy of Urban Renewal in Southwest Washington, D.C." *Journal of Planning History*, Vol. 8, No. 3: 175-220.
- Asch, C., and G. Musgrove. 2018. *Chocolate City: A History of Race and Democracy in the Nation's Capital*. Chapel Hill: University of North Carolina Press.
- Berman v. Parker, 348 U.S. 26 (1954).
- Brown v. Board of Education of Topeka, 347 U.S. 483 (1954).
- Chronopoulos, T. 2014. "Robert Moses and the Visual Dimension of Physical Disorder: Efforts to Demonstrate Urban Blight in the Age of Slum Clearance." *Journal of Planning History*, Vol. 13, No. 3: 207-233.
- Ferguson, R. 2004. *Aberrations in Black: Toward a Queer of Color Critique*. Minneapolis: University of Minnesota Press.
- Foucault, M. 1995. *Discipline and Punish: The Birth of the Prison*, (1975). Translated from the French by A. Sheridan. New York: Vintage Books.
- Foucault, M. 1990. *The History of Sexuality. Volume 1: An Introduction*. Translated from the French by Robert Hurley. New York: Vintage Books.
- Fraser, N. 1997. "Heterosexism, Misrecognition, and Capitalism: A Response to Judith Butler." *Social Text*, No. 52/53: 279-289.
- Frisch, M. 2002. "Planning as a Heterosexist Project." *Journal of Planning Education and Research*, Vol. 21, No.3: 254-266.
- Gunder, M., and J. Hillier. 2003. "Planning Fantasies? An Exploration of a Potential Lacanian Framework for Understanding Development Assessment Planning." *Planning Theory*, Vol. 2, No. 3: 225-248.
- Gunder, M. 2005. "The Production of Desirous Space: Mere Fantasies of the Utopian City?" *Planning Theory*, Vol. 4, No. 2: 173-199.
- Gunder, M. 2011. "A Metapsychological Exploration of the Role of Popular Media in Engineering Public Belief on Planning Issues." *Planning Theory*, Vol. 10, No. 4: 325-343.
- Heap, C. 2009. *Slumming: Sexual and Racial Encounters in American Nightlife, 1885-1940*. Chicago: University of Chicago Press.
- Lavine, A. 2010. "Urban Renewal and the Story of Berman v. Parker." *Albany Law School Research Paper*, No. 10-05: 423-475.
- Lefebvre, H. 1991. *The Production of Space (1974)*. Translated by D. Nicholson-Smith. Oxford: Blackwell Publishers Inc.
- Marx, K. 1983. *Capital (1867)*. Edited by E. Kamenka. New York: Penguin Books.
- Melamed, J. 2011. *Represent and Destroy: Rationalizing Violence in the New Racial Capitalism*. Minneapolis: University of Minnesota Press.
- Mitchell, D. 2003. *The Right to the City: Social Justice and the Fight for Public Space*. New York: The Guilford Press.
- Omi, M., and H. Winant. 1994. *Racial Formation in the United States*. New York: Routledge.
- Robinson, C. 2000. *Black Marxism: The Making of the Black Radical Tradition*. Chapel Hill and London: The University of North Carolina Press.
- Said, E. 1979. *Orientalism*. Vintage Books Edition. New York: Pantheon Books.
- Sandercock, L. 1998. *Making the Invisible Visible: A Multicultural Planning History*. Los Angeles: University of California Press.
- Shanken, A. 2018. "The Visual Culture of Planning." *Journal of Planning History*, Vol. 17, No. 4: 395-406.
- Yiftachel, O. 1998. "Planning and social control: Exploring the dark side." *Journal of Planning Literature*, Vol. 12, No. 4: 300-319.

BENDING PARABOLAS: Formwork for Compression-only Structures

Wesam al Asali¹, Thomas Reynolds² & Michael Ramage¹
¹University of Cambridge, ²University of Edinburgh

Abstract: The “elastic” curves formed by a uniform buckled strut are not optimal shapes as guidework and formwork for compression-only structures. In this paper, we adapt the family of elastic curves to vaults and arches, by changing the stiffness of the strut to force it to buckle as a parabola. The approximation of elastica to parabola in a bent strip makes it useful to form-find, support, and guide the construction of vaults. Consequently, an average variation of the stiffness will form a strip that always generates parabolic arches as it moves, opens, or closes. Hence, the strip becomes a tool that always finds and describes multiple vaulted geometries that otherwise require complicated, one-use, and bulky formwork systems. The system was tested with thin-tile vaulting through building three thin-tile vaults using the bending system for simple in-situ construction.

Finding simple in-situ solutions for compression-only structures advocates local grassroots construction that seeks alternatives, not only to the way we build now, but also to the way we think about design. The production of the built environment is not always in the hands of architects and engineers; a dialogue between high-knowledge analysis and low-tech everyday construction is much needed. In this particular context, the paper proposes optimizing on-site technology through design analysis that focuses on the dialogue between material behavior and craftsmanship.

Keywords: Active bending, thin-tile vault, construction, geometry

INTRODUCTION

In both traditional and contemporary architecture, making compression-only shells requires a set of temporary structures that either support or guide the construction. Shells and the formwork with which they are built have critical reciprocity. The selection of materials and techniques has immediate implications on the type and intensity of the formwork; some structures require complete shuttering, while, for others, specific techniques can be used to mitigate shuttering. This can be observed in the way that different construction cultures respond to the abundance or scarcity of materials by adopting different formwork techniques for vaults. The abundance of wood and labor in the western areas of the Roman Empire resulted in concrete vaults with full shuttering (Lancaster 2015). The lack of timber in Mesopotamia and Egypt produced an architecture of mud blocks that relinquishes formwork altogether; it cheats gravity by changing the paths of the successive bedding so that a brick is always leaning on a previous brick (Ramírez Ponce and Ramírez Melendez 2004; Wendland 2007). In the current application of this construction, builders often resort to a hanging rope or chain fixed on both ends of a vault to help them visualize the perfect arch even in a reversed fashion. In thin-tile vault construction, a masonry construction technique of Mediterranean origin, heavy formwork is avoided with the use of fast-setting plaster of Paris and light tiles to build a first layer that serves as the formwork for more layers (Truño i Rusiñol et al. 2004; Ochsendorf 2010).

Today, we aim for construction that is conscious of material and energy consumption, as well as waste production; hence, reducing or recycling the materials used for formwork becomes critical. Many approaches to “rethinking formwork” have been suggested since the beginnings of mechanized construction. Geometry-oriented solutions offered ruled surfaces that reach complex structures by repeating a linear element. Examples of this approach can be found in the architecture of Antoni Gaudí, who used a hyper-parabola for thin-tile vaulting guidework, and Felix Candela, who used similar systems for the shuttering of concrete shells. Use-oriented solutions re-employ formwork materials for furniture or other building components, or for a stay-in-place part of the shell (Ramage et al. 2010; López López, Van Mele, and Block 2018). There are many recent technology-oriented solutions, including: the use of three-dimensional printing for making shells over curved surfaces composed of piles of gravel or soil; robotic arms that temporarily carry vault bricks; and net-cable systems with fabric that are made for concrete shells (Zivkovic and Battaglia 2018; Wu 2018; Van Mele and Block 2011).

In this paper, we return to the raw status quo of the formwork problem, that is: How can the perfect form of structural arches be captured? In other words, since the perfect form for compression-only structures is shaped, in Robert Hook’s words, “as hangs the flexible line”, the main objective of this paper is to flip Hook’s flexible line to serve as formwork. For this purpose, we investigate

the use of the elastic curve of a buckled strut as a method for a flexible formwork for compression-only shells.

1. BACKGROUND: BENDING FOR FORMWORK

If we could flip a hanging chain and keep it solid, this would be a perfect guide or formwork system for masonry or cast vaulting. However, we usually engineer such temporary structures using wood, steel, or other materials. One such system is based on elasticity: strips or surfaces are bent for vaults. Bending to create guidework in construction is not a new technique. In fact, the construction of thin-tile vaults incorporates bent elements: traditionally, reed and, recently, steel reinforcing bars (rebar). Diagonally oriented rebar is wedged between the vault's corners to mark the curvatures for sail or cross vaults.

Bending follows an elastic curve, whereas the line of thrust in compression-only structures follows a catenary, or a parabolic curve, if loaded with equally distributed loads. At moments of minimum bending, the two curves are very similar. Thus, a slightly bent steel bar aids the thin-tile vault builder, as it is close to the parabolic section. However, when bending with more acute angles, the two curves begin to diverge drastically, and the bent steel bar is no longer valid as a reference for vaulting. Figure 1 shows the different behaviors between bending steel bar and hanging a chain, where the deviation between the two is shown in relation to different angles of bending.

From mapping the behavior of the two curves, the divergence becomes noticeable when the height of the elastic curve is more than half of its span (figure 1). Traditional builders recognize this problem and have solved it by anchoring two sides of the steel rebar with strings, bringing the elastica back to a parabola. For more recent advanced fabrication techniques, the controlled active bending of wood is being explored through kerf bending or using bi-layer structures in which joints have two parts, one of which can move while the other restrains movement (Capone and Lanzara 2019; Baseta and Bollinger 2018). In both approaches, the freedom provided by the joints or cuts is what drives the movement; however, they are usually predesigned for a specific "target curve" and require intensive advanced fabrication work.

2. METHOD: BENDING TO A PARABOLA

Our approach to control bending is easy to accomplish with regular tools. We propose that merely changing the stiffness of the material along the strut leads to an approximation of the bending curvature to a parabola. This can be achieved by adding and subtracting material at a given location along the strut, which modifies

the bending stiffness, and thus the curvature at that location. The stiffness profile along the strut can be chosen to alter the shape of the curve, and with the appropriate profile, it is physically possible to form a parabola. Two main equations were used to analyze the stiffness change along the section and determine the variations: the buckling equation (elastic curve) and the parabola equation. The two equations were set to give a stiffness variation for a curve at a specific height and span (figure 2). For the resultant strip, the overall shape is the graph of the stiffness (figure 2).

A parabola is defined by Equation (1), where x and y are cartesian coordinates and a and b are constants; a is the maximum height, y , and if the span between zero heights is l , then b is given by $b=4a/l^2$. Differentiating this equation twice gives an expression for the required radius of curvature, R , at a given x coordinate, in Equation (2).

$$1. \quad y=a-bx^2$$

$$2. \quad R(x)=\frac{(1+(2bx)^2)^{2/3}}{2b}$$

If a force, P , is applied horizontally along the dotted line in figure 1, the moment at a given point in the strut is Py . For an elastic strut to buckle into this shape, its stiffness must satisfy the bending equation, Equation (3).

$$3. \quad M=Py=\frac{EI(x)}{R(x)}$$

Substituting (1) and (2) into (3) gives an equation for the bending stiffness of the strip per unit of applied force P , as shown in Equation (4).

$$4. \quad EI/P=(a-bx^2)\left(\frac{(1+4b^2x^2)^{2/3}}{2b}\right)$$

To find the required stiffness at a particular point along the length of the strut, we must convert from the cartesian coordinate, x , to a distance along the strut, s . The incremental distance, ds , is defined in terms of the incremental coordinates dx and dy by Equation (5).

$$5. \quad ds=\sqrt{dx^2+dy^2}$$

Since $y=a-bx^2$, Equation (5) can be used to give an expression for s , Equation (6), yielding the relationship between x and s given by Equation (7).

$$6. \quad s=\int_0^x \sqrt{1+4b^2x^2} \, dx$$

$$7. \quad s=\frac{2bx\sqrt{4b^2x^2+1}+\sinh^{-1}(2bx)}{4b}$$

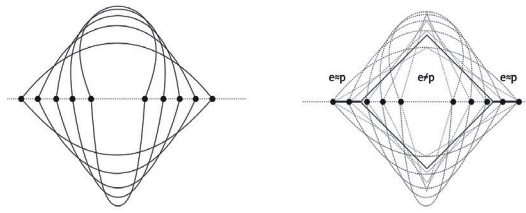


Figure 1: Elastica and parabola comparison (left). Divergence between elastica and parabola with more bending (right). (Author 2019)

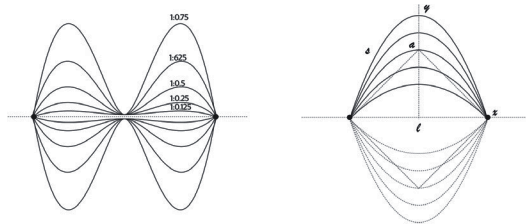


Figure 2: Changing stiffness diagrams in relation to rise-to-span ratio of curves (left). Results from approximation (right). (Author 2019)

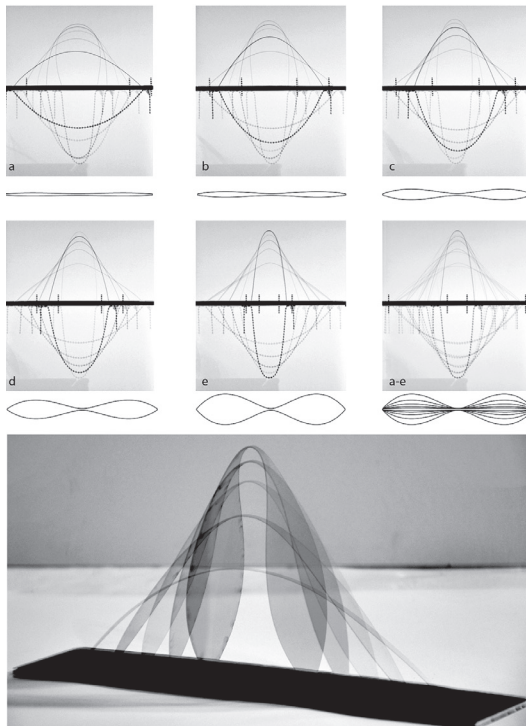


Figure 3: Testing: geometrical study of bending with different fusiformed strips (Author 2019)

Equation (4) thus gives the required stiffness, EI , at any horizontal coordinate, and this horizontal coordinate, x , can be transformed into a distance along the strut using Equation (7). These two equations give a relationship between the coordinate along the strut and its stiffness that allow the strut to be cut to the required shape. This can be done either by altering the width of the strip, which is proportional to EI , or the thickness of the strip, which is proportional to $\sqrt[3]{EI}$.

The shape of the strip is now two fusiform geometries. The maximum thickness is at the middle of each half before decreasing towards the center (figure 2). The change in thickness is moderate for nearly flat bending. In other words, at ratios of span-to-height of (1:0.25) or (1:0.5), the fusiform shapes are almost unrecognizable. A difference emerges with significant bending at a ratio of (1:1) or (1:2). There is no particular shape that can always give an exact parabola at any moment of bending, which is a limitation of such methods. However, an acceptable range of deviations can be accepted, primarily when the approximated strips are used as guidework or formwork for vaults, which usually have thicker sections.

To look for an average shape whose strip can cover a broad spectrum of parabolas that are constructionally acceptable as formwork, pieces of polypropylene with different span-to-height ratios were laser cut into parabolas with ratios of (1:0.25), (1:0.5), (1:0.75), (1:1), and (1:1.25). The physical testing showed that the range of shapes with curves with ratios from (1:0.75) to (1:1) can give a parabola, even for much steeper ratios (figure 3). For higher ratios, when the fusiform is very pronounced, shallow bending will create straight lines on the side, and the curvature will be restricted to the middle area, where the material is very thin.

The tool in hand, now called the *bending parabola*, can be used to devise an elastic guidework for a parabolic arch as it closes and opens. Sweeping, revolving, and shifting create sections of the bending parabola and generate multiple geometries of vaults. This strip then offers the possibility for an autonomous in-situ form-finding of structures, using simple materials such as rebar, wood, and bamboo.

The bending parabola can be used as a generative tool for many shapes. If we consider using only a linear element of the bending parabola (a strip) and move it on a rail to make a curve extrusion, we encounter several iterations of vaults with parabolic sections. The geometrical study of possible tracks in figure 4 shows various possibilities of vaulting that can be generated with the same bending parabola. Structural and design studies of such typologies become inherent in the tool, and they can be made without thinking about or designing one-time-use molds.

Bending Parabolas

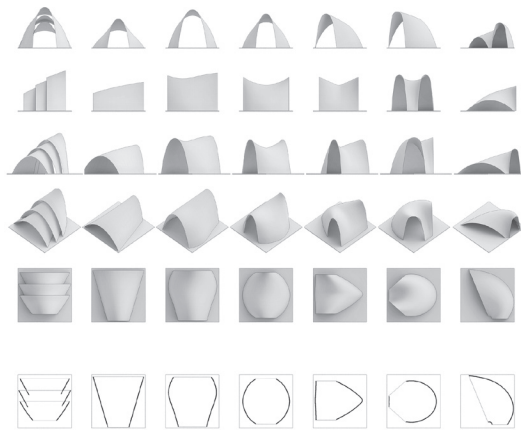


Figure 4: Possible vaulted geometries using the bending parabola (Author 2019)

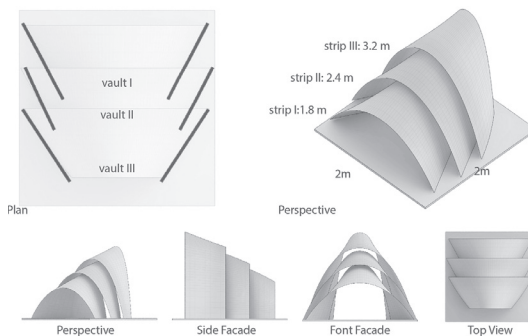


Figure 5: Vault composition from three bending parabolas (Author 2019)

3. RESULTS: AN APPLICATION

3.1. DESIGN: THIN-TILE VAULT

An application of the bending parabola was tested for use with the thin-tile vault technique. The traditional thin-tile vault construction can be found in Spain. Using terracotta tiles and plaster, builders construct various traditional vault typologies, such as ceilings of small vaults on steel or wooden beams, barrel vaults, and vaulted stairs. The thin-tile vault technique requires skill, but the few steps of construction, namely adding the plaster to the tile and then placing it on the vault, can be quickly learned. However, it is difficult to regulate the overall curvature of the vault or arch by controlling the placement of each tile. For this reason, a guidework to help visualize a structure is recommended for complex designs or for novice builders. Here, the bending parabola becomes useful.

The geometrical configuration of a vault was selected from the options in the previous geometrical study in figure 4. A structure containing three vaults with three different parabolic sections arranged from small to large was selected because it offers the possibility to

test the tool's limitations for construction. The structure comprises three vaults, each of which is built with a strip of a specific length: 2.8, 3.4, and 4 meters. Consequently, each vault has a maximum height of 1.2, 1.5, and 1.8 meters, respectively. Due to the self-generated shape of the vault, no sections or drawings with precise dimensions were prepared as the change of height of each vault is generated by the bent strip (figure 5).

3.2. MATERIAL

An inquiry into a suitable material to make the strips was required. In an effort to avoid construction using advanced fabrication machinery, we adopted a lamination method to change the section of the bending parabola. The first option we examined was wood, which bends with an acceptable range of small thickness and long length. However, wood knots present an obstacle that can obstruct a uniform bending curve, and formed weak points are fragile against strong bending forces. Bamboo has nodes but no knots, which results in an enormous curve when bent, making it the most suitable material.

A small verification test was performed with bamboo blades, which were first bent without any additions and bent again with additional layers that were manually added to the middle quarters of the length and attached with tape. The test proves that the approximation by laminas helps bring an elastic curve to parabolas. Manual lamination also provided greater control of the ratio of thicknesses to achieve the target arch, since laminas can be added or removed as needed (figure 6).

3.3. CONSTRUCTION

The construction was done with the help of an expert in thin-tile vaults and stair making from Valencia. During an introductory meeting, we discussed the method and process of the construction, which involved a simple plan involving rails along which the parabolic strips would sweep. No plans or sections were introduced to the builder, and only the bamboo strips were provided.

To build a thin-tile vault with a sequence of arches, the first arch should be supported by formwork or a wall (Truño i Rusiñol et al. 2004), while later arches can be formwork-free because each tile has at least two edges with plaster, which is sufficient to support the tile. In the case of this parabolic vault, the bamboo worked as both formwork and guidework. Switching between the two roles was possible by adding or removing bamboo strips underneath the vault. Three bamboo strips, for instance, were sufficient to create a robust formwork for the smaller vault, whereas only one strip was needed for the guidework. The flexibility of changing between the two functions was advantageous in terms of accelerating the work and saving the formwork material (figure 7).

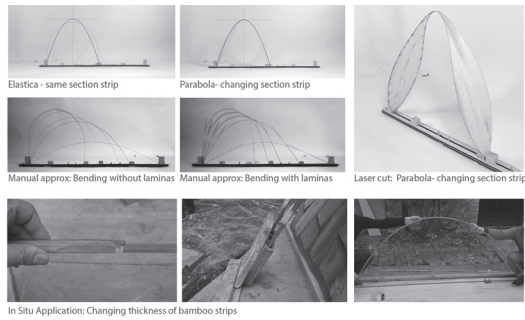


Figure 6: Approximation to parabola using laser cutting for changing the strip's thickness (top). Manual thickness variation using bamboo laminas (bottom). (Author 2019)



Figure 7: Thin-tile vault construction details (Author 2019)

3.4. A LEARNING TOOL

During construction of the largest vault, the mason found that the surface of the vault was reachable through an incremental three-dimensional rotation of tiles along the arch. This made construction possible without bent bamboo beneath the arches. Instead, we placed one bamboo strip at the end of the tile to serve as a visual guide for construction. In this instance, the tool become obsolete, but only after it served as a teaching element even for a skilled mason. It helped him to acquire the skills and knowledge required for building the specific thin-tile vault typology of a diverging parabolic vault.

The three parabolic vaults prove that the inherent properties of materials, bamboo and tiles, together provide several solutions to find a construction language using simple in-situ tools. In addition to the bending parabola, we used a conventional Catalan trowel, plaster, and tiles. The waste material from the formwork and guidework were only the tape used to fasten the bamboo strips together, as the strips themselves were returned to the material workshop almost as usable as when we first obtained them.

To avoid movement at the base of the bamboo during construction, we anchored the poles at each end

in the holes of bricks, which were fixed to the ground with plaster of Paris (figure 6). After setting the base of the three vaults, we began with the smallest to learn how the bamboo would act during construction. The bamboo generated a parabolic arch and performed well for construction. When we reached the largest vault, the strip became very long, and the manual lamination of the strips resulted in deviations and asymmetries in the parabolic shape that necessitated delaminating the strips and correcting the positions of the laminas to perfect the curve (figure 7).

CONCLUSION

Bending a homogenous element creates an elastic curve. Elastics cannot be used as, or for, compression-only structures, but the change of stiffness, or the amount of the material, of the bent element can provide a rough approximation for compression-only structural shells. Therefore, by changing the shape of strips, we explored different bending behaviors, one of which is a specific a strip with the shape of two fusiforms that creates a parabolic curve when bent. With a strip whose stiffness is high towards the first quarter and low towards the end and middle, one can form-find the compression-only structures in-situ by merely bending the strip: we call this the "the bending parabola". Adding stiffness to specific areas in the strip can be done by cutting, lathing, or laminating. Using the laminating method, three thin-tile vaults were built to examine the effectiveness of the bending parabola. The construction techniques and tools were the same for each vault: the strip, which served as a form-finder so there was no need for drawings, a formwork, which supported the thin-tile vault during construction, and a learning tool, which showed the artisan how the tiles should be positioned to achieve a specific form.

Rethinking materials for new systems of guidework and formwork can result in new methods of construction, especially when linked to geometry. When structures are understood as the materialization of their inherent material properties, bending for compression-only structures not only produces buildable vaults but also makes possible geometries that result from, and are described by, simple in-situ applications. Finding simple in-situ solutions for compression-only structures can become a driver of local grassroots construction that seeks alternatives not only to the way we build now but also to the way we think about design. The production of the built environment is not always in the hands of architects and engineers. In 2030, one in four people will be living in informal contexts, so an examination of and dialogue between high-knowledge analysis and low-tech everyday construction are much needed. In this particular context, the role of architecture is to mediate



Figure 8: Thin-tile vault result (Author 2019)

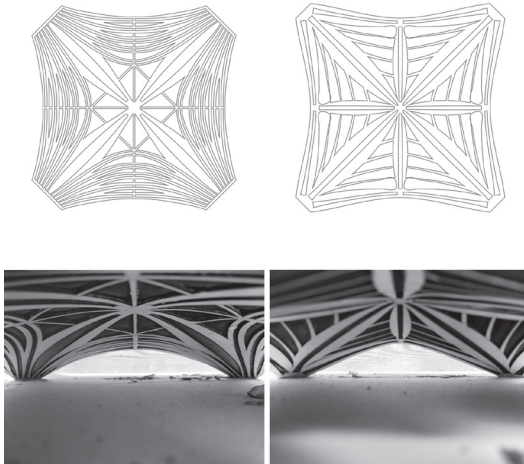


Figure 9: Bending plates for structural shells, patterns are studied to approximate bending curves to catenary sections (Author 2019)

between materials, craftsmanship, and physics. An obvious example of this is the construction of Gaudí's ruled-surface vaults, where he combined ruled-surface logic with traditional string guidework. Gaudí's alteration of fabrication was not significant, in that the tools were still everyday strings, but he transformed them into a somewhat unprecedented mechanism for producing complex geometrical compositions.

Originally, the research focused on splines or the sequence of sections to generate geometries of compression-only shells. The next step is to work with sets of elements that work together as one system to describe a complex surface of a compression-only structures (figure 9). The move into bending plates offers a divergence from thin-tile vaulting (where the bent structure is a guidework) towards considering using bending-active systems as flexible formwork



Figure 10: Thin-tile vault result (Author 2019)

for lightweight compression-only concrete slabs or as lightweight flat-packed structures.

"Bend and build" should be explored more as it is underused given the ubiquity of linear elements in nature—bamboo and reed canes—and in the engineering and construction industries. This paper focuses on bent linear elements and their movements to produce thin-tile shells with parabolic sections (figure 9). Entirely new possibilities can now be opened in the study of surfaces, which is the topic of our ongoing research.

ACKNOWLEDGEMENTS

The authors would like to thank the master vault maker Salvador Gomis Aviño. This research is part of Al Asali's MPhil and Ph.D. on thin-tile vaulting, both funded by the Cambridge Trust-Saïd Foundation's scholarship.

REFERENCES

- Baseta, Efilena, and Klaus Bollinger. 2018. "Construction System for Reversible Self-Formation of Grid Shells. Correspondence between Physical and Digital Form." In *ACADIA 2018: Recalibration. On Imprecision and Infidelity*. Proceedings of the 38th Annual Conference of the Association for Computer Aided Design in Architecture (ACADIA) ISBN 978-0-692-17729-7]. Mexico City, Mexico, October 18-20, 2018, 366-375.
- Capone, Mara, and Emanuela Lanzara. 2019. "Parametric Kerf Bending: Manufacturing Double Curvature Surfaces for Wooden Furniture Design." In *Digital Wood Design: Innovative Techniques of Representation in Architectural Design*, edited by Fabio Bianconi and Marco Filippucci, 415–39. Lecture Notes in Civil Engineering. Cham: Springer International Publishing.
- Lancaster, Lynne C. 2015. *Innovative Vaulting in the Architecture of the Roman Empire: 1st to 4th Centuries CE*. Cambridge: Cambridge University Press.
- López López, David, Tom Van Mele, and Philippe Block. 2018. "The Combination of Tile Vaults with Reinforcement and Concrete." *International Journal of Architectural Heritage* 13, no. 6 (June, 2018): 782-98.
- Ochsendorf, John. 2010. *Guastavino Vaulting: The Art of Structural Tile*. 1st edition. New York: Princeton Architectural Press.
- Ramage, Michael H., John Ochsendorf, Peter Rich, James K. Bellamy, and Philippe Block. 2010. "Design and Construction of the Mapungubwe National Park Interpretive Centre, South Africa." *ATDF Journal* 7, no. 1: 14–23.

Bending Parabolas

- Ramírez Ponce, Alfonso, and Rafael Ramírez Melendez. 2004. "Curves of Clay: Mexican Brick Vaults and Domes." In *Nexus V: Architecture and Mathematics*, edited by Kim Williams and Francisco Javier Delgado-Cepeda, 143–54. Florence: Kim Williams Books.
- Truño i Rusiñol, Àngel, Santiago Huerta Fernández, José Luis González Moreno-Navarro, Esther Redondo Martínez, Instituto Juan de Herrera, and Escuela Técnica Superior de Arquitectura de Madrid. 2004. *Construcción de bóvedas tabicadas*. Madrid: Instituto Juan de Herrera, Escuela Técnica Superior de Arquitectura.
- Van Mele, Tom, and Philippe Block. 2011. "A Novel Form Finding Method for Fabric Formwork for Concrete Shells." *J. Int. Assoc. Shell and Spatial Structures* 52: 217–24.
- Wendland, David. 2007. "The Vaults in 'Sistani's House' in Bam Citadel (Iran) : Construction Principles, Shape Geometry and Design for Reconstruction." In *Interim Report for a Rehabilitation Project for Sistani's House, Bam Citadel Radebeul*, by Wolfram Jäger, 48–51. Hunter Consulting Engineers.
- Wu, Kaicong. 2018. "Robotic Equilibrium Scaffold Free Arch Assemblies." In *ACADIA 2018: Recalibration. On Imprecision and Infidelity*. Proceedings of the 38th Annual Conference of the Association for Computer Aided Design in Architecture (ACADIA) ISBN 978-0-692-17729-7]. Mexico City, Mexico, October 18-20, 2018, 342–49.
- Zivkovic, Sasa, and Christopher Battaglia. 2018. "Rough Pass Extrusion Tooling. CNC Post-Processing of 3D-Printed Sub-Additive Concrete Lattice Structures." In *ACADIA // 2018: Recalibration. On Imprecision and Infidelity*. [Proceedings of the 38th Annual Conference of the Association for Computer Aided Design in Architecture (ACADIA) ISBN 978-0-692-17729-7] Mexico City, Mexico 18-20 October, 2018, 302-311. CUMINCAD.

HOW ENERGY MAKES A DIFFERENCE ON THE MORPHOLOGY OF SPACE

Mark Balzar
University of Applied Arts Vienna

Abstract:

According to the theory of relativity, there is no essential distinction between mass and energy. Energy has mass and mass represents energy. Instead of two conservation laws, we have only one, that of mass-energy. (Calaprice, Dyson, and Einstein 2005, 390)

In today's sciences we pay a great deal of attention to the complexity of biological form and ecological formation. Analogies in urban research refer to cities as living (eco)systems, organisms or technological artifacts, which follow the rules of an urban metabolism. All these narratives seem to suggest that all matter (acting and interacting) on earth belong to a complex whole and their physiological characteristics share common organizational physical laws, which are rather dynamic and formless by their nature. A quantitative and qualitative theory for understanding these complexities and the dynamics of such a condensed organization of urban organic and inorganic materialization remains elusive, however, its impact on our planet is explicit and evident in various forms. Currently, most of humanity lives in cities. Their organization of human society and the tendency of cities to grow put ecological pressure on the global environment.

The urban realm is an ever-unfolding amalgam of the biosphere and the techno-sphere within a dynamical system of materiality which threatens the concept of static form as an expression of physiological states. This formlessness is rather an expression (and empowering) of emerging patterns than an ambiguous loss of control. This paper argues that developing a new theoretical measure of understanding the materiality of forms, and the formation of the urban realm(s) as the effect of a complex information system of interrelations seems to be necessary. The following text will discuss the trajectory through three major approaches: The philosophical concept of (New) Materialism in relation to discursive formations (a terminology developed by Michel Foucault), the scientific concept of Systems Ecology of Howard T. Odum and the theoretical concept of *individuation* by Gilbert Simondon (1992). Systems ecology grants a view to dynamism of the physical, chemical, economic, and social forces in the field of urban morphological ensembles—the passive potentialities (energy storage) and the active transgressing forces (energy transfer) governed by the second law of thermodynamics. Odum's understanding of urban energy cycles bears the potential to unravel the information patterns of an urban organism controlled by time.

Keywords: Theory of urbanism, ecology, energy, individuation

1. THE EMERGENCE OF FORM OR HOW TO BECOME FORM: A PHILOSOPHICAL APPROACH

Every building and urban assembly, every technological machine, every artificial and biological entity, is organismic. Alfred North Whitehead's organic theory establishes an ontological framework for a philosophy of organism and the theoretical concept of process at the production of the world, which is organized through relations rather than constants and facts. He proposes actual entities (present real objects resultant from a historical process) of which potential entities evolve. In Whitehead's (1979) ontology, every real physical entity, is organismic and is a representative object of the metaphysical world.

The philosophy of organism is closely allied to Spinoza's scheme of thought. But it differs by the abandonment of the subject-predicate forms of thought, so far as concerns the presupposition that this form is a direct embodiment of the most ultimate characterization of fact. The result is that the 'substance-quality' concept is avoided, and that

morphological description is replaced by the description of the dynamic process. . . . it does not lead us to any higher grade of reality. The coherence which the system seeks to preserve, is the discovery that the process, or concrescence, of any actual entity, involves the other actual entities among its components. In this way, the obvious solidarity of the world receives its explanation. (Whitehead 1979, 7)

In philosophy, there are many concepts elaborating on the force behind the materialization of objects and form in the physical and metaphysical realm. Especially the philosophy of New Materialism finds its inspiration by the concepts of Aristotle's *entelechy*, which has been further developed by German developmental biologist Hans Driesch as the life force, Spinoza's substance, Leibniz monad, or later Bergson's *élan vital*. All these ideas are united by the anxiety to explain the very origin and force behind the becoming of things.

How Energy Makes a Difference on the Morphology of Space

In the early 19th century, the British physician Thomas Young established the term energy for the driving force behind biological life. The origin of the term energy refers to the old Greek word *energeia*, which means potentiality and actuality, which on the other hand are translations of the Greek word *dunamis*, meaning possibility or capability. The same terminology was embraced and further conjoined to thermodynamic principles behind chemical processes by the mathematician Rudolf Clausius and the scientist Josiah Willard Gibbs. Together with Hermann von Helmholtz's experiments on the relationship between mechanics, heat, light, electricity and magnetism via the manifestation of a single shared force, they paved the way for Cybernetics and System Ecology, by approaching the perception of physical material and materialization through a process of energetic transformation.

From a New Materialist point of view, the order of origin, hence the relation between different objectives is dependent on physical proof and the concepts originating in physical and mathematical scientific frameworks. A logic-based coherence on the matter of thought depends on indefinite physical properties. Materiality, therefore, can only reveal itself in relation and in correlation with other matter and its depending properties. The binding forces are the sheer expression of related forms. This translates into every event being the result of a material cause, following other causes in relation to and depending on prior events. Independent from the point of observation these events take place according to their own invisible set of relationships but can be revealed or followed up through apparent phenomena in the workings of matter and energy.

With the ontological framework of the plane of immanence, consisting of assemblages within emergent ensembles, Gilles Deleuze and Felix Guattari create a theoretical machinery of multiplicities (bodies or effects of temporary phenomena derived from diverse interrelated substances) made up of many heterogeneous forms of existence which establish relationships between them. Forms enroll within the plane of immanence (Gilman et al. 1989), a theoretical cartography of relationships. These organs or "bodies" of interiority (related to French physiologist Claude Bernard's 'Milieu intérieur', 1854) are of a contingently stable nature. They form fragile substantial parts within and among bodies, as bodies of bodies, or parts of parts—thus they form systems of relations of exteriority and interiority, establishing the appearing nature of a complex whole. For the most part, those organismic bodies are of an autarchical nature, only communicating to the outside world through its permeable system boundary. This boundary appears to the outside world as an object involved in a continuous reshaping process.

Gilbert Simondon (2017) refers to this process of becoming of an object or gaining identity as 'individuation' (1992), a continuous informative and transformative process of communication creating technological as well as biological form. The process includes the development of its own skills, abilities, perspectives, and relationships, until it reaches a permanent state. Within this context, the expression of temporary effects of permanent relations is understood as individuating forms on the plain of immanence. A designed entity is therefore not only a (active or passive) part of a larger system and the expression of the ongoing forces within its own system, but it individuates from that very same system of interrelations, operating and acting permanently within it. The resultant formation of the informed object intrinsically maps its territory, discovers its own dynamic forces and relations, as well as their relative limits through and within all scales. Transformation and change are immanent and part of that nature.

2. HOW MATERIALITY BECOMES AN EXPRESSION OF ENERGY STORAGE OR INFORMATION (CODE) (WHITEHEAD'S OBJECTS)

If we consider buildings as atoms of urbanism, in the realm of chemistry, the periodic table of elements defines a clear system and diagram of materiality and material performance, depending on their subatomic nucleons and electrons. In a rigorous way, all elements have been ordered and organized by their atomic number (number of protons), and electron configuration as indicators of potential chemical properties or trends. The number of protons in the nucleus of the atom and electrons play a very essential part in defining individual properties of elements given by the importance of atomic behavior within their relationship as molecules. If there is an imbalance of electrons and protons in the nucleus then this element will behave as electronically charged and therefore defined as *ion*. The energy to free the electron with the least binding force to the core from the nucleus is called *ionization energy*, which also is a measure of the strength of electron bonds in molecules. (Feynman, Leighton, and Sands 2011).

The energy to free an electron from an atom and forces it to travel across elements - the origin of the transfer and storage of (digital) information - creates energetic transfer in form of electric impulses, which leaves traces in the environment through the consequently charged elements or through energetic loss. Electric current defines the flow whereas static electricity (storage) defines the potential flow. Electricity, in this case, is the result of a chemical engine driven by energetic instability with the potential to even change the nature of elements and therefore molecules

themselves. It is also within this flow of electrons where biological and technological matter merge into an amalgam of vital materiality and the laws of physics start to shape our existence and our environment.

With a thorough and thought-provoking text, the neurologist Wolf Singer (2002) posed the question whether the physiological structure of the brain could be used as a model for urbanism. He describes the process of information transfer from the corporeal immune system to the brain and draws parallels to urban structures. The immune system is limited to the physical transfer of information via molecules given the fact that it is physiologically incapable of being active through electric charge. Here the nervous-system comes into play. Those cells are activated through key substances and via electrical impulses so complex information can be transferred over long distances to the brain. Two systems merge through interaction and, as a result, two topologically independent entities are made possible. Singer concludes that through these organized architectures it is possible to overcome the limits of cartesian space, enabling highly complex structures like the human body to be realized. Structural complexity is in direct proportion to storage capacity and the quality of information. In this sense, digital technologies and the internet merge together with the built environment to become one complex urban realm.

3. THE AMALGAM OF NATURE AND TECHNOLOGY AT THE LEVEL OF URBAN ECOLOGY

Considering the history of urbanism, we witness in various stages and velocities the effects of an intensifying bio-technological synthesis throughout society. Understanding chemical and physical processes inherent in both nature and technology is key, in order to reveal the genuine concepts originating in complexity science, cybernetics, and systems theory. The urban realm, therefore, is the largest bio-technological organism to observe this condition.

Across various disciplines, a new cultural paradigm in understanding and treating our environment and the humanities as distinct but interdependent entities, a major draw from the complexity sciences, has caused a shift in the perception of contemporary society and the world we live in. For example, in Luis M. A. Bettencourt's research paper on the physical laws of quantities and qualities of urban growth, he argues, that cities are consumers of energy and resources and producers of artifacts, information, and waste which have often been compared with biological entities.⁷

They further argue in their paper, "that many diverse properties of cities from patent production and personal income to electrical cable length are shown to be power law functions of population size with

scaling exponents, β , that fall into distinct universality classes. Quantities reflecting wealth creation and innovation have $\beta \sim 1.2 > 1$ (increasing returns) whereas those accounting for infrastructure display $\beta \sim 0.8 < 1$ (economies of scale). . . . The predominance and universality of quarter-power scaling have been understood as a manifestation of general underlying principles that constrain the dynamics and geometry of distribution networks within organisms" (Bettencourt et al. 2007, 7301-7306). What is crucial at this point is that these principles of scaling laws developed for cities do not have an equivalent in the biological realm. Social network effects, wealth, and economic systems are human centered and others like building mass and infrastructure are pure technological contributions at the overall urban scale.

Ecological efficiency and energetic optimization of organisms (e.g. the metabolic rate related to the body mass index or the bifurcation of rivers and the related volume to speed ratio depending on the surface of the river bed), are phenomena of physics (Bejan and Zane 2012) which are related to the *dynamic energy budget theory*. Accordingly, these are embedded strategies of the 'geochemical energy' flow of life in the biosphere (Vernadsky 1997). As an example, used materials, architectural forms and building typologies do influence urban environments and their immediate ecosystems. There are various studies on the phenomenon of urban heat islands causing climatic shifts and *metabolic rifts*, not only at the microscale, but also at the ecological macro scale. In Phoenix, Arizona, the specific use of building materials in combination with built form has rechanneled wind behavior and contributed to significant local temperature increase causing more regular and intense-tornados overall. In *Delirious New York* (Koolhaas 1979) Rem Koolhaas describes the intensification of the urban grid and built environment working as a social condenser, where the outright increase in numbers (buildings, population, social differences, etc.) causes a social and cultural revolution.

If we understand energy as the capacity to do work, the reverse, stored energy in matter itself, represents the history of the labor involved to create the current state, as well as the reservoir of potential energy flow. The first law of thermodynamics states that energy changes form but never completely vanishes (Schneider and Sagan 2005). The second law of thermodynamics states that the total entropy of an isolated system will never decrease over time, and is constant if and only if all processes are reversible. Isolated systems spontaneously evolve towards thermodynamic equilibrium, the state of maximum entropy. By the same token, a regular pattern emerges from the flow of energy-cycles of alternating

How Energy Makes a Difference on the Morphology of Space

intervals between high sectoral growth and intervals of relatively slow growth.

Urban formations with their increased complexity are condensers of such energetic resources and potentials.

4. SYSTEM THEORY, COMPLEXITY SCIENCE AND URBANISM

According to Odum, "culture is the shared program of behavior of a population that organizes the individual, the group, and the environment into high-quality systems adapted to its energy regime and providing services to its territory." (Odum 1971, 509)

The technological and biological amalgam of *homo urbanus* is involved in an inseparable symbiosis with the chemical and physical environment of the natural artificiality of cities, including its digital environments (e.g. the digital economy and social networks). This fusion composes a new urban condition of a spatio-dynamic complex system, which demands a reconfiguration of the inherent infrastructure and redefines its local and its global status. Both positions depend on its being perceived as an Open System (Variable Environment) or as a Closed System (Constant Environment). In mathematical and computational sciences, this rigorous differentiation leads to a simplistic concept of reality in order to gain a better understanding of biological systems. In biology the observed organisation unfolds in such complex form, where both presuppositions are only differentiated through a scalar permeable system boundary.

Variable Environments require sufficiently fast adaptation and populations where tunable error rates will adjust their quasi species to meet the environmental challenge. In constant environments, on the other hand, such species will tune their error rates to the smallest possible values in order to maximize fitness. (Langton 1995, 46)

5. A COMPUTATIONAL (ARTIFICIAL) APPROACH TO BIOLOGICAL SYSTEMS THROUGH THE SCIENCE OF THEORETICAL BIOLOGY - CYBERNETICS VS GENERAL SYSTEM THEORY

An open system is defined by Ludwig von Bertalanffy as a system exchanging matter with its environment, presenting import and export, building up and breaking down of its material components. A system will be referred to as 'closed' if no material enters or leaves it. This system has a boundary condition, which keeps it internally stable and organizes its behavior within a closed environment upon which it can operate.

An organism, however, is not a closed system in thermodynamic equilibrium, but an open system in a (quasi-) stationary state with another one, equifinality (Von Bertalanffy 1969). Within the concept of an open

system the term, equifinality, defines the principle of achieving a stable state or goal through various potential means.

In this-sense, the equifinal self-preservation of the organism is opposed to a physical system which tends towards a state of highest probability of maximal disorder. Hence the general tendency of all systems to reach equifinality (for each individual species), through the procedure of entropy, causes the constant adaptation of an organism leading to an interdependent global morphology. Therefore, the living organism is maintained in a continuous exchange of components called metabolism.

After certain conditions, open systems approach a time-independent state, the so-called steady state. If the phenomenon of a steady state is reached in an open system, it is independent of the initial conditions, and determined only by the system parameters. This equifinality appears therefore-as a quasi-optimized closed system.

The basis of the open system is the dynamic interaction of its components. The basis of the cybernetic model is the feedback cycle, in which, by way of feedback of information, a desired value is maintained, a target is reached.

Herein lies a clear theoretical difference between both approaches. Whereas the first system theoretically is an infinite process, the second one becomes static as it reaches the target value (Von Bertalanffy 1969).

The clear gap between the two concepts of open system versus closed systems was addressed by a theory developed by Herbert A. Simon (H. A. Simon 1969) regarding artificial systems that he calls "Near-Decomposability." His idea derives from the consideration of a modular system consisting of separable and identifiable models or components of a larger realm, like buildings within a city. He coined this approach through the term 'modularity' (H. Simon 2005), which means full decomposability or almost no interdependence between modules. A decomposable system is modular in that each component or module operates primarily according to its own, intrinsically determined principles. Each component is dependent upon inputs from other components—it influences other components only by its outputs—and has a specific intrinsic function. In the case of biological evolution, the primary function is phenotypic selection, where the genes affecting the complex character have a high degree of internal integration and a low degree of external connectivity.

Thinking of cities, the urban realm defines a model for a general theory of a spatio-dynamic formation, through information transfer within the hybridization process of technology and nature. The awareness

of these diverse modes of existence of materializing objects (through the energetic transfer of material and information) indicates the process of evolving multiplicities (a condition of being many things at once of urban form, through the permanent production and reconfiguration of multiple forms at various scales (house, area, district, ...). Therefore, the city, like any complex form of life, concerns the problem of the becoming of form and formation of the many vibrant object[ive]s.

6. SYSTEMS ECOLOGY - A MATHEMATICAL CONCEPT OF THE BIOLOGICAL ENVIRONMENT THROUGH THE APPROACH OF CYBERNETICS AND GENERAL SYSTEMS THEORY

The ecologist Howard T. Odum contributed a very complex approach, not only to perceiving the built environment, but the general biological and abiotic ecosystem at large. In the late 19th century, the Viennese geologist Eduard Suess had coined the term biosphere for the place on the surface where life prospers (Suess 2019). This new terminology was followed and further developed by the Russian ecologist Vladimir Vernadsky. Odum, who found inspiration in Vernadsky's work, states that the biosphere is the largest ecosystem, but argues further that all parts (or organisms), referring to forests, the seas, or even great cities, are ecosystems too. All these different subsystems and parts of parts (Odum 1971)² operate according to their expenditure of energy following the second law of thermodynamics.

Flows of genes, books, television communications, computer programs, human culture, art, political interactions, and religious communications are examples of information. However, these all have very large embodied energies and high ratios of calories of solar energy per calorie of information. However, these all have very large embodied energies and high ratios of calories of solar energy per calorie of information. It is still appropriate to consider the calories of potential energy in information, since this is what drives the depreciation and loss of information as with losses of other kinds of storage.

Information cannot be stored without some concentration of substance or energy fields relative to the environment. For example, words on a page are concentrations of ink, memory on a computer disk is a concentration of magnetic field, and information in biological genes is a storage of DNA form relative to the environment.

The flows of information carry the most embodied energy and also have the greatest amplifier and control effects per calorie. They are the feedbacks of highly embodied energy that provide systems with specialized services, feeding back positive actions that "repay" their webs for the energy dispersed in the development of the information.... Information pathways are energy pathways. (Crawley and Odum 1984, 19)

7. ODUM'S CONCEPT OF ENERGY THROUGH ENERGESE: ENERGY SYSTEMS LANGUAGE

Odum termed "energeses" (Odum 1988) an integrated approach in ecology used to describe the natural processes of adaptation and selection, which relied on the definition of an entity as a combination of properties keeping some stability over time—very much like Lotka's ideas on the energetics of evolution (Lotka 1922). Odum was also inspired by the ideas of the Russian ecologist Alfred J. Lotka who argued that natural selection will occur out of an evolutionary process of energetic flux within our biosphere—energy as the worldly substance, as well as cause of change.

Joining the evolution of the complex forms of organisms and matter and unraveling the mechanisms immersed in a ceaseless stream between different entities and within one entity (which is a matter of scale, time, space and historicity), the very notion of the phenomenon called life itself was effectively the focus of Odum's scientific and theoretical oeuvre. Embedded in theoretical biology and inheriting the aforementioned concepts of general systems theory and cybernetics, Odum's research on systems ecology was a very thorough and rigorous effort in understanding ecological systems through a new geography of energy flows. All configuration of biomass and abiotic matter is describable via the significant contributions to energy flow and energy storage (including the deposit of hydrocarbons in the earth, which have fueled the social and technological revolution of the past 150 years), the energy degraded and left behind, and its inherent transfer and transformation of information. The actual form as it is perceived at the time of observation expresses and is a measure of all the energy (quality) used in its making. This temporary status quo of contained energy derived from and embedded within an evolutionary process is defined by Odum as "energy". Energy describes the qualitative difference of various forms of energy at a measured state derived throughout the history of energy. For example, fossil fuels deriving from the degradation of a biomass also inherently present the solar radiation through photosynthesis of millions of years ago, as well as the degradation and transformation of its energetic process. Energy is contained within all existing substance and its materialization and expresses the potential as free energy or energetic transformation.³ Odum's ideas were conceived as an integration of cybernetic theory into the research field of ecology and informed the formulation of systems ecology. In his ecological (and biochemical) theory, all physical environments of biology and technology belong to a greater realm (or organism) subdivided into various fields or microclimates transgressing and circulating, not only

How Energy Makes a Difference on the Morphology of Space

energetic quantities, but also qualities of different sets, or set of sets, very much akin to Herbert Simon's theory of modularity.

As previously stated, energy never vanishes but is in constant circulation or otherwise stored, until it is relieved from its passive state (a temporary stable appearance of form). Materiality conforms itself to the combustion of historicity and presence in time and space, forming a unique moment of quality and potential, until energy progresses onward.

Within this thermodynamic process, the term exergy (Rant 1956)⁴ represents the available energy (work) to be used, and describes the relationship in terms of a combination property of a system and its environment. Contrary to energy, an indicator of the history of metabolism, exergy is not transferred into another property but is destroyed during the irreversible process of transformation (biological or ecological evolution)—for example by the release or loss of heat. Energy language reduces ecosystems into system boundaries (defining open and closed states of the indicated system), forcing functions, state variables, process pathways, transgressing velocities of energy qualities, sinks, and material networks based on mathematical equations and logics.

8. MORPHOGENESIS

The science of systems ecology developed an understanding of the materialization of organic as well as inorganic form to be the result of interrelated physicochemical systems—interactive and entangled elements through interrelated forces—which are acting and interacting upon each other. These systems are no more than very complex energetic cycles, and autocatalytic loops of interrelated chemical substances in a constant *tour de force*, in order to achieve physical stability through the change of formation and the exchange of information. These processes master thermodynamic principles in order to achieve the ultimate balance within competing influences—also called the final equilibrium or steady state in order to succeed in evolution. This eternal stable state of a process (form), which only exists in theory, is the result of all forces resolving to zero.

Odum's model of morphogenesis derives from Einstein's Theory of Relativity. Einstein states with his minimalistic but very complex formula, that every mass that is in motion is in direct relationship to an energetic counterpart. It is an entangled pair that never drifts apart. Therefore, we can measure the value of energy transgressing through the physical realm via the velocity and the mass of all particles dancing and orchestrating in friction to the rhythms of the metabolic concert of nature.

9. EVOLUTION OF FORM

To understand the fundamental principles of the evolution of living and non-living matter as one concert of energetic flux, constant cycles of transgressing, degrading, and dispersing particles in one space and one time, puts this motion directly in the context of thermodynamics. As the biologist Conrad Waddington, who laid the foundations of systems biology, states, "because of their inherent analytical complexity, biological concepts in general imply a multidimensionality" (Waddington 1978; Gilbert 1991). This multidimensionality belongs to the many coexistent superimpositions in phase space which defines identity through a field of locality, instead of actual points. Phase Space maps all potential states of a dynamic system where each iteration of a process leads to a different, spontaneous outcome. It postulates that our environment is the actual result of a (thermo-)dynamic process of spontaneous events, of which the phenomenon of the urban realm consists of subdivisions of differentiated bodies within a (spatio-)dynamic form(ation) in energetic flux. These subdivisions of subdivisions are in constant relation through leaking information (leakages through the systems boundary). Buildings, infrastructure, political institutions, economic systems, or social bodies are all biodiverse organisms and organs of organisms. These different complex forms of urban aggregation are gradient static expressions of representative forms of one moment in time.

10. WASTEFUL LIFE OR ENERGY EFFICIENCY?

The space that labor and technical know-how open to the increased reproduction of men is not, in the proper sense, one that life has not yet populated. But human activity transforming the world augments the mass of living matter with supplementary apparatuses, composed of an immense quantity of inert matter, which considerably increases the resources of available energy. (Bataille 1991, 36)

Georges Bataille argues that all life that matters ordinarily receives more energy that is necessary for maintaining life but this leads to the excess (wealth) that contributes and is essential to the growth of all systems. Without the gainful production of surpluses, life itself stagnates and, regarding thermodynamic principles, relaxes to steady state. The urban realm is nothing else than a condensed storehouse and engine of energy production and transformation. The myriad forms of urban life and matter are an assemblage of energy of various qualities, states, and excess resources, in relation with local biomass, matter, and the climatic geological and geographic conditions. These diverse forms of an ecosystem are under constant pressure and friction with its neighbors given the limited available space on earth.

The expenditure of luxurious and exuberant energy puts pressure on the formation of matter in space and drives order into chaos, transgressing energy into various subordinate realms. For Bataille, every form of available energy must lead to some form of gainful work, or it will be otherwise destroyed through unproductive use. The ground of this operation is little more than a field of multiple destructions where the surplus energy, mainly entering the world system through solar radiation, transgress into subordinate fields of lower order forms and then disappear. It follows that the squandering of energy in every form is a principle of living matter. Every form of organism depends on the favorable contribution from others (which also is a form of destruction), in order to survive as a species. This functional activity is nothing other than the vital force behind any form of biologic life and its energetic life cycle. The excessive use of energy provides the necessary turbulence in life, in order to keep it alive. Bataille concludes that real excess does not begin until the growth of the individual, or the process of individuation has reached its limits or final state, though a more immediate limitation is given by the other individuals or groups and the available space. The physiological shape is the descriptive geometry of relationships, which represents the atmospheric boundary where the assembly of individual objects is in dialogue through different levels of feedback operations. The object circumscribes the various layers and stages of the same system.

If biology breaths through its myriad forms, an ecosystem evolves in whichever form(ation) evolution might take it, and technology proceeds within or separate with the former, then all emergent states are an expression of life and energy itself.

CONCLUSION

By extending the scope of urbanism to the process of anthropogenic metabolism⁵ a new “lens” of information fields can be established, where hidden causalities beneath the surface can be discovered. These potentially contribute to a holistic understanding of the ongoing mechanisms and generative resources which are immanent to the entities of objects, biomass and the heritage of information (history) at an urban scale. Architects should investigate the discrete multiplicities which make a difference, even at the smallest scale. They should take a closer look at the traits of resemblance among properties, similarities of processes of different kinds and different morphologies within the realms of energy and culture. In the Deleuzian sense, the trajectory follows the singularities, the “*implicit forms that are topological rather than geometric*” (Gilles Deleuze 1987, 408). It all leads to an understanding of form to derive from its dependencies and interdependencies of its related compounds.⁶

Scale-dependent observation does not exist independent of the observer. It is particularly relevant in ecology, the science of complex systems ranging from the bacterial realm to the global Biosphere. (Vernadsky 1997, 30)

The urban realm is a complex amalgam of infrastructure, architecture, and biology in an interplay of energetic forces. Odum's research shows that in the biological realm an ecologic system is far healthier and superior, through “looping” (recycling and up-cycling) energy and materials and by infusing these loops at intervals with fresh external energy.

Odum had a very clear view on the substance of the reality of the spectrum of energy, as emergent properties and qualities of next order forms with different hierarchical relationships and energetic life cycles. Past, present and future are not separate entities but actors in the same field. With Odum's approach, phenomena of the biological and urban realm could be discussed on multiple levels (political strategies, private interests, economic value, efficiency in design and materialization, ecological function of the public realm, ...) and different scales. What kind of materials do we use? How much external energy do we need to produce these building materials and which global economic pathways are involved with their various effects on a local scale?

Odum's urban matter relates on a field of processual activity with different forces simultaneously at play. Classic theories and models of urbanism consider a reductionist view of static formations of architectural forms, but do not account for emergence and the emergent properties of its energetic evolution.

In a wider sense, systems ecology relates to the seminal works of Walter Christaller's *Central Place Theory* (Christaller 2009; van Meeteren and Poorthuis 2018), as well as Christopher Alexanders groundbreaking work on *A Pattern Language* (Alexander, Ishikawa, and Silverstein 1977; Alexander, n.d.) and his theories on morphogenetic processes in architecture and urbanism. All these approaches opposed the static model of architecture and urban form. Systems ecology grants a view towards the dynamism of the physical, chemical, economic, and social forces in the field of urban morphological ensembles—the passive potentialities (energy storage) and the active transgressing forces. Odum's understanding of urban energy cycles becomes even more valid in evaluating extensive datasets and the effects of technological innovation, in order to unravel the information patterns over time. Here, it is necessary to differentiate the parametric model related through quantities, from the dynamic model of qualities through emerging patterns over time. These forms are not a matter of typologies. They are transformative qualities of differences in motion—descriptive inherent properties of relations.

ENDNOTES

- 1 Luis M.A. Bettencourt, Lobo Jose, Dirk Helbing, Christian Kühnert, and Geoffrey West. 2007. "Growth, Innovation, Scaling, and the Pace of Life in Cities." *PNAS* Vol.104, No.104: 7301-7306
- 2 *Concepts of the structure and function of the natural world emerged as parts within parts within parts* (Odum 1971, 2).
- 3 Science distinguishes between Gibbs free energy as available energy calculated through the maximum of reversible work that may be performed by a thermodynamic system at a constant temperature and pressure or Helmholtz free energy is a thermodynamic potential that measures the useful work obtainable from a closed thermodynamic system at a constant temperature and volume [www.sciencedirect.com/topics/earth-and-planetary-sciences/free-energy]
- 4 The concept of exergy has been developed by J. Willard Gibbs, but the term was first mentioned by Zoran Rant in 1956.
- 5 Anthropogenic metabolism, also referred to as 'metabolism of the anthroposphere', is a term used in industrial ecology, material flow analysis, and waste management to describe the material and energy turnover of human society.
- 6 Manuel Delanda. 2013. *Intensive Science and Virtual Philosophy*. First Edit. London, Oxford, New York, New Dehli, Sydney: Bloomsbury Academic.

REFERENCES

- Alexander, C. 1966. "A City Is Not a Tree," *Design*, No. 206 (February): 46-55.
- Alexander, Christopher, Sara Ishikawa, and Murray Silverstein. 1977. *A Pattern Language: Towns, Buildings, Construction*. Edited by Max With, Jacobson, Ingrid Fiksdahl-King, and Shlomo Angel. Berkeley: Oxford University Press.
- Bataille, Georges. 1991. *The Accursed Share: Volume 1*. First Pape. New York: Zone Books.
- Bejan, Adrian, and Peter J. Zane. 2012. *Design in Nature: How the Constructal Law Governs Evolution in Biology, Physics, Technology, and Social Organization*. New York, London, Toronto, Sydney, Auckland: Doubleday.
- Bertalanffy, Ludwig Von. 1969. *General System Theory: Foundations, Development, Application*. Revised Ed. Georg Brazier, Inc.
- Bettencourt, Luis M.A., Lobo Jose, Dirk Helbing, Christian Kühnert, and Geoffrey West. 2007. "Growth, Innovation, Scaling, and the Pace of Life in Cities." *PNAS* Vol.104, No.104: 7301-7306
- Calaprice, Alice, Feeman Dyson, and Albert Einstein. 2005. *The New Quotable Einstein*. *Adsabs.Harvard.Edu*.
- Christaller, Walter. 2009. *Die Zentralen Orte in Süddeutschland: Eine Ökonomisch-Geographische Untersuchung Über Die Gesetzmäßigkeit Der Verbreitung Und Entwicklung Der Siedlungen Mit Städtischen Funktionen*. Nachdr. 19. wbg Academic in Wissenschaftliche Buchgesellschaft.
- Crawley, M. J., and Howard T. Odum. 1984. "Systems Ecology. An Introduction." *The Journal of Animal Ecology* 53, no. 2 (June): 695-6.
- Delanda, Manuel. 2013. *Intensive Science and Virtual Philosophy*. First Edit. London, Oxford, New York, New Dehli, Sydney: Bloomsbury Academic.
- Feynman, Richard P, Robert B Leighton, and Matthew Sands. 2011. *The Feynman Lectures on Physics, Vol. I: The New Millennium Edition: Mainly Mechanics, Radiation, and Heat*. *European Journal of Physics*. New York: Basic Books.
- Gilbert, Scott F. 1991. "Epigeneti Landscaping: Waddington's Use of Cell Fate Bifurcation Diagrams.Pdf." *Biology and Philosophy* 6: 135-154.
- Gilles Deleuze, Felix Guattari. 1987. *A Thousand Plateaus: Capitalism and Schizophrenia*. Edited by Brian Massumi. 2nd Editio. Minnesota: University of Minnesota Press.
- Gilman, Sander L., Gilles Deleuze, Felix Guattari, and Brian Massumi. 1989. "A Thousand Plateaus: Capitalism and Schizophrenia." *Journal of Interdisciplinary History* 19, no. 4: 567. <https://doi.org/10.2307/203963>.
- Langton, Christopher G. 1995. *Artificial Life: An Overview*. *Artificial Life*. London: The MIT Press. <https://doi.org/10.2307/1575317>.
- Lotka, Alfred J. 1922. "Contribution to the Energetics of Evolution." *Proceedings of the National Academy of Sciences* 8 (6): 147-51. <https://doi.org/10.1073/pnas.8.6.147>.
- Koolhaas, Rem. 2002. *Delirious New York: Ein Retroaktives Manifest für Manhattan*. Translation by Fritz Schneider. Aschen: Arch Verlag.
- Meeteren, Michiel van, and Ate Poorthuis. 2018. "Christaller and 'Big Data': Recalibrating Central Place Theory via the Geoweb." *Urban Geography*, 1: 122-148. <https://doi.org/10.1080/02723638.2017.1298017>.
- Odum, Howard T. 1971. *Environment, Power, and Society*. New York, London, Toronto, Sydney: Wiley Interscience.
- Odum, Howard T. 1988. "Self-Organization, Transformity, and Information." *Science - New Series* Vol. 242, No.4882: 1132-1139.
- Rant, Zoran. 1956. "Exergie, Ein Neues Wort Für 'Technische Arbeitsfähigkeit'." *Forschung Auf dem Gebiete des Ingenieurwesens*, 22: 36-37.

- Schneider, Eric D., and Dorion Sagan. 2005. *Into the Cool: Energy Flow, Thermodynamics, and Life*. London: The University of Chicago Press.
- Seuss, Eduard. 2019. *Die Entstehung Der Alpen*. Bremen: Inktank publishing.
- Simon, Herbert. 2005. *Modularity: Understanding the Development and Evolution of Natural Complex Systems. The Vienna Series in Theoretical Biology; Foreword by , Herbert A Simon*. Edited by Werner Callebaut and Diego Rasskin-Gutman. Cambridge Massachusettes: MIT Press.
- Simon, Herbert A. 1969. *The Science of the Artificial*. Third Edit. Cambridge: MIT Press.
- Simondon, Gilbert. 1992. "The Genesis of the Individual." In *Incorporations (Zone 6)*, edited by Jonathan Crary and Sanford Kwinter, 297–319. New York: Zone Books.
- Simondon, Gilbert. 2017. *On the Mode of Existence of Technical Objects*. Minnesota: University of Minnesota Press.
- Singer, Wolf. 2002. "Die Architektur Des Gehirns Als Modell Für Komplexe Stadtstrukturen?" In *Der Beobachter im Gehirn: Essays zur Hirnforschung*, 8th ed., 153 - 161. Berlin: Suhrkamp Verlag.
- Vernadsky, Vladimir I. 1997. *The Biosphere*. New York: Springer-Verlag.
- Waddington, Conrad Hal. 1978. *The Man-Made Future*. London: Croom Helm Ltd.
- Whitehead, Alfred North. 1979. *Process and Reality*. Edited by David Ray Griffin and Donald W. Sherburne. Corrected Edition. New York: Free Press.
- Wiener, Norbert. 1965. *Cybernetics: Or the Control and Communication in the Animal and the Machine*. Cambridge: MIT Press.

ARCHITECTURAL MUTATIONS OF INDIVIDUAL HOUSES IN THE SAHARA DESERT: Case of Algerian Sahara

Yassine Mohammed Benyoucef
Andrey Razin Dionisovich
Peoples' Friendship University of Russia

Abstract: The residential architecture in the Algerian Sahara passed through several phases from the precolonial period to the current period. The precolonial period was characterized by traditional (vernacular) architecture with a compact urban fabric but, during the colonization, these communities became subject to architectural and social destruction. At the same time, the appearance of new models for architecture and cultural organization, the European way of life generated by the French colonization, triggered major architectural and urban changes. At independence, the official urban practice was to maintain continuity and relay colonial laws and architectural and urban orientations.

Today, the housing sector in the Algerian Saharan cities faces many problems. In each city, the explosion of housing is manifest as several housing types. Moreover, the inhabitants spontaneously try to transform their habitat according to their image of modernity. Methodologically, an analysis of the different demographic and socio-cultural mutations is made, moreover an architectural analysis during the main three phases starting from the precolonial period until now. This article will give an overview of the mutations and transformations of individual habitation typology in the Algerian Sahara. These mutations were multi-level, urban, architectural, and sociocultural.

Keywords: Individual houses, architectural mutations, housing typology, Algerian Sahara

INTRODUCTION

The Sahara is considered the largest desert, and the best illustration of hot deserts in the world; the extensive hot desert, characterized by its extreme aridity, is located in the northern part of the African continent (Lewis and Berry 1988, 155). In Algeria, it occupies more than 80% of the total surface of the country; the climate is characterized in particular by the weakness and the irregularity of precipitation, high temperatures, an intense luminosity, and strong evaporation (Chehma 2011). The Saharan cities, and more generally the Saharan territories today, under many influences and beset by complex and rapid changes, are faced at times with problematic issues (Kouzmine 2007). The Algerian Saharan territories have been characterized by strong social and spatial mutations. Saharan cities in pre-colonial residential architecture were dominated by *vernacular architecture*. The start of colonization is marked by radical architectural and urban interventions on existing urban fabrics, demolitions, and transformations of existing buildings. The Saharan societies were subjected to the destruction of the spatial and social structures (Sriti and Tabet-Aoul 2004) that underlie the growth of human settlements, which led to a disruption of the diverse tradition and architectural heritage of the Saharan region. On the other hand, these also lead to the emergence of different architectural patterns and sociocultural organization, as well as to the emergence of a new way of life, especially the European lifestyle resulting from colonialism. These

significant changes, in architectural dimensions and large-scale mutations, brought some benefits but also many problems, on many levels. Moreover, during colonialism, many architectural styles and typologies emerged, such as classical, neoclassical, neo Moorish, Modern). After independence, the official urban and architectural practice was to emphasize continuity and maintain colonial laws with the introduction of some new laws.

Algerian Saharan houses have undergone changes over time and upheavals that have altered their main characteristics. The predominance of the individual house in Algeria in the structure of the housing stock according to the census is 55, or 26%, a metric evidenced by the increasing number of housing estates, prevalent in Algerian cities. The traditional house represents only 16, or 78% of the total individual houses (Benzaoui 2013).

The main purpose of this paper is to provide an overview of the mutations and transformations of individual habitation in the Saharan region; these mutations can be represented at many levels, urban, architectural, social, cultural, and political, in order to find the most influential and important factors that should be taken into account when designing a modern Saharan house.

The issue of housing in all its complexity has occupied an important place in political discourse in the past three decades in Algeria, during which multiple

Architectural Mutations of Individual Houses in the Sahara Desert

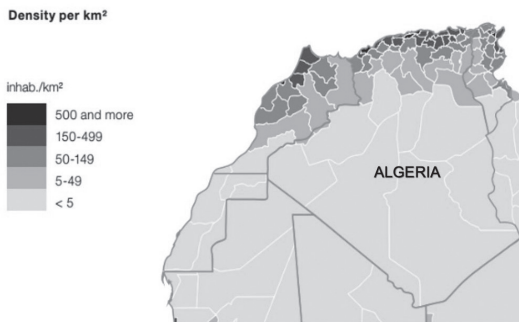


Figure 1: Population density in the Sahara (www.diva-gis.org/gdata)

crises have struck the country due to the various mutations that occurred in the Algerian Sahara region, the different transformation of the typology of the Saharan house (Badr-Eddine 2013), and the absence of supervision and legal frameworks. Moreover, there exists a lack of modern designs that take into account the many characteristics of the region and the desert community. Today, the Saharan family spontaneously tries to transform their habitation according to the image they have of modernity. All and all, it has led to several architectural and urban problems.

1. DEMOGRAPHY AND MUTATIONS

In Algeria, more than 80% of the area is the Sahara. In this zone, many urban agglomerations represent a diversity in the lifestyle of these regions, which translates into a variety of architectural representations and urban organizations. The Algerian Sahara has experienced profound demographic changes since the middle of the 20th century (Kouzmine 2007). The urbanization rate of the Saharan population was around 10% in 1954, while, in 1998, at the last general population and housing census (R.G.P.H.), this rate was 63% (Hammoudi 2014). Between 1954 and 2008, the urban population multiplied by 16, reaching 2.5 million citizens in 73 cities (Kouzmine and Fontaine 2018), in the last 10 years this population has reached 3.6 million citizens.

2. PHASES AND ARCHITECTURAL MUTATIONS IN ALGERIAN SAHARA

Most of the Algerian cities in the Sahara Desert are characterized by the same process of evolution of their urban fabrics and architectural typology (Boudiaf 2003). This architectural, urban mutation has undergone three main phases (Sriti and Tabet-Aoul 2004):

1. The traditional phase (Before 1830)
2. The colonial phase (1830-1962)
3. The post-independence phase. (After 1962)

These mutations caused changes in the physical and morphological aspects of a city, by affecting spatial organization and the evolution of urban and architectural forms, these mutations may take different forms, among them:

1. *Morphological mutation.* This mutation affects the morphology of the Saharan city in terms of the urban forms and architectural style, represented in two main urban tissues (traditional, colonial).
2. *Functional mutation.* This type of mutation implies changes in the functions fulfilled by an urban or architectural space (traffic, housing, activities).
3. *Social-cultural mutation.* The change in the social composition of the population, the latter defining social practices, traditions, and lifestyle between two modes of life (oriental, Western).
4. *Political and economic mutation.* This mutation implies changes in state policy or a comprehensive change to the government system, in addition to the economic transformations of the country.

Residential architecture and especially individual housing types; have experienced many changes in typology, stylistic qualities and spatial organization. These changes have undergone several phases.

2.1. TRADITIONAL PHASE: THE VERNACULAR HOUSE

Saharan cities in the pre-colonial era were dominated by the traditional architecture (Ksar, Kasbah) types, which are characterized by compact form on the urban level and a vernacular architecture, whose typology and specificity showed Arab, or Berber influences. Often, these cities were surrounded by a vast palm grove (Oases). Traditional dwellers in Sahara Desert oases have survived by sheltering and protecting themselves from the extremes in climatic conditions using vernacular building techniques developed by experimentation through the ages (Dabaieh 2011). Desert dwellings have always been effective in terms of their adaptation to the harsh climatic conditions (Benyoucef and Razin 2018). Cities follow the forms of vernacular architecture (figure 2), largely due to the influence of the environment. The term "vernacular architecture" is used to refer to traditional buildings that have been designed and built to match the local climate and culture, and how what was built in the desert areas differed in the urban configuration and construction material from what was built in other areas.

Generally, houses are compact with a closed outer face, the urban layout is similar in most of the Sahara cities (Francesca 2006). The patio house type is considered one of the most important typologies of the vernacular house in the Sahara. Thus, this traditional dwelling is characterized by hierarchization

of spaces, integration with climate, site, the socio-cultural dimension, and the use of local materials, such as adobe, rammed earth, and stone. Traditional houses form the base in a large number of different cities; these include a central organization and are built around a single central courtyard (Patio). The courtyard is cut off from the street by a completely blind wall, and sometimes this wall can contain a very small windows measuring 20x35 cm; the entrance to the house is through a chicane space locally called "Sguifa", which gives indirect access to the central courtyard (Bousquet 1986), which itself gives access to other rooms of the house "byut".

2.1.1. PATIO HOUSE

Most of the traditional houses in Saharan cities are patio houses with introverted organization. They represent the most common houses module in Saharan cities; the patio is a kind of microcosm that connects the house with nature, sky, sun, fresh air, earth, water, and vegetation, and becomes a space that offers natural ventilation to the rooms; the plans of houses are about 8-15 m in width (Benyoucef and Razin 2018). The patio is a typical space of vernacular houses, and is defined by a perimeter gallery present at each floor, which creates a transit area between the central courtyard

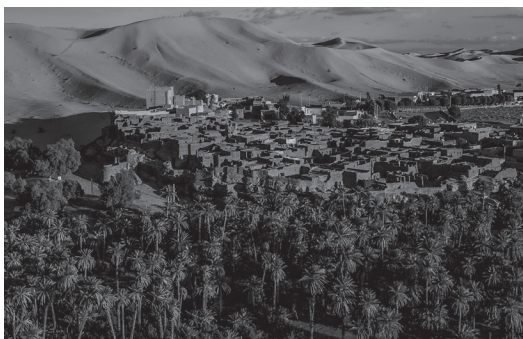


Figure 2: Algerian Saharan cities with vernacular architecture, 1) urban view of the city of Ghardaia (top). (George Steinmetz). 2) Timimoun city in Gourara oases (bottom). (Rachid Imekhllef)

and the private rooms (Benyoucef and Suslova 2019). Moreover, the patio is considered a living space for women and children, for preparation, and for family celebrations. To understand the features of the general design of desert houses, we can mention different houses from four different Saharan cities that are characterized by an introverted and central organization of spaces, Beni-Izghen (figure 3.1) and Ghardaia (figure 3.2), Oud Souf (figure 3.3), Kenadsa (figure 3.4).

It is virtually impossible to find two identical houses in the traditional cities, but some basic characteristics are similar, such as the general organization with the central patio, which allows us to make a general description of the typical Saharan house. Most of the houses present a central organization around a courtyard, which is the main typology of Saharan houses that give big importance to the central space and the indirect relation between the exterior and the interior of the house. The exterior facades, in general, are characterized by simplicity and small rectangular windows; often the facade is completely blind, in contrast to the interior facade that contains large windows and some decoration. This exterior facade characteristic results from pure climatic and socio-cultural requirement, as the small exterior windows also have a ventilation role; figure 4 represents two different facades in Taghit (Bechar) and Ghardaia cities in Algerian Sahara.

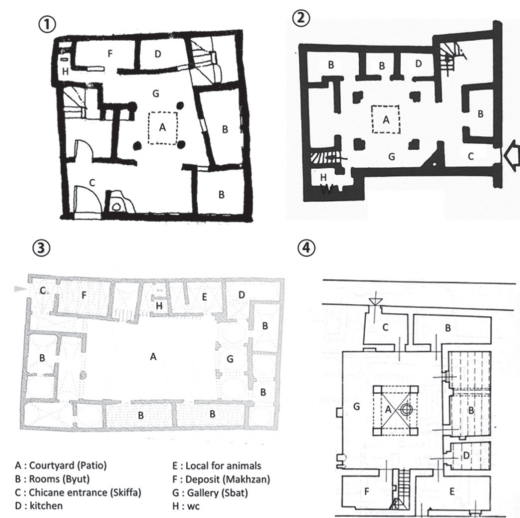


Figure 3: Four different traditional houses with central patio in different Algerian Sahara cities: 1) Traditional house plan in Beni Isguen (Bousquet C. 1983). 2) Traditional house plan, with central Patio, Ghardaia (J. Eshalie). 3) Plan of traditional house in Oud Souf (Belhadj N. 2011). 4) House with four pillars at the ksar of Kenadsa (Bachminski J, Grandet D, 1985; Treated by the author).

Architectural Mutations of Individual Houses in the Sahara Desert

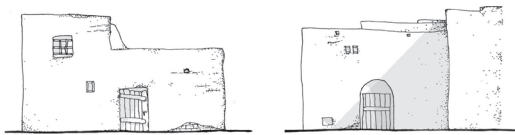


Figure 4: Facade of traditional house in Taghit (Bechar) (left), facade of traditional house in Ghardaia (right). (Author 2019)

The building materials used in vernacular houses are mainly adobe, stone, raw brick, earth, lime, and palm wood. The use of local materials with high thermal inertia, like adobe or rammed earth, are very important for climatic adaptation in hot, arid regions (Nefidi and Oukaci 2017). Today, the traditional house has undergone changes and upheavals over time that have changed its main characteristics. It has also changed the relationship between the interior and exterior of the dwelling, as manifest in the opening and widening of the openings facing the street. This type has been subject throughout history of a significant evolution, following the changes in contemporary uses of housing that tends to all that is modern (Benzaoui 2013).

2.2. COLONIAL PHASE: COLONIAL HOUSE

By 1830, the French colonial presence in Algeria brought a noticeable change in the architectural landscape of cities. The evolution of the architecture is influenced by the introduction of a new model of the city and architecture in total rupture with the traditional architectural model, which is completely ignored by the colonizers. The arrival of French colonialism in the nineteenth century represented the first break in terms of organization and urban functions (Kouzmine 2007). Colonial architecture in Algeria (1830-1930) was derived from nineteenth centuries of architecture in European cities.

During the French colonial period, the dominant feature of this transformation was the construction of European houses (Hadjilah 2016). Large portions of the cities in Algeria were destroyed for the installations of the military and the first settlers (Aleth 1994), and the creation of new residential districts (Sriti and Belakehal 2002). The forms of these houses are strongly inspired by European architecture and a western way of life. Turning their backs on traditional architecture, the houses open to the street by moving the central courtyard to the back of the house, these are the first fruits of extroversion. The access to the interior is directly from a corridor or hall (Hamouda and Abdou 2013).

Generally, individual houses take many forms during the colonial phase; the houses of the Europeans in the first suburbs after colonization are terraced and aligned on the street with one floor or two floors. They are characterized by an extroverted organization of

spaces, large windows, the ornamentation of facades according to the style of the city, sloped or flat roofs and the presence of a courtyard and side gardens. The colonial house was generally built of raw brick, the façade was perfectly symmetrical about an axis that coincided with the middle of the main entrance door, and the roof covered with a double sloped tile. The internal spatial organization was along a corridor that serves the different rooms, and conforms to the interior organization of the western house, but there are also houses where the internal organization is similar to the precolonial house. The land parcel was always bigger than the parcel in the traditional cities. The "corridor house" (figure 7) is considered a new architectural type that emerged during this period in Algerian cities (Boutabba and Farhi 2014); this type prevailed between the seventeenth and nineteenth century in almost all French regions.

The Muslim population (1830-1930) was living in ksours, kasbahs, and indigenous villages. As soon as these original urban cores became saturated, they settled in slums on the outskirts of cities that sometimes became neighborhoods of one or two-story houses. Their configuration was halfway between the house of the Kasbah or ksar, very simplified with a courtyard, and the European house with windows on the street (Bouchentouf 2017). Muslim neighborhoods and European neighborhoods were clearly distinct with respect to their urban organization and the aspect of their architecture (Lalonde 2010, 29).



Figure 5: Colonial architecture (Arabesque style), Bechar city. (www.judaicalgeria.com)

In the early years of the colonial period, the architectural formations of houses were influenced by the classical European style, with the nomination of Charles Celestin Jonnart as governor-general (1903). Jonnart published a series of circulars to impose a certain architectural style on public buildings, thus, he became the initiator of a new stylistic movement with oriental tendencies: the neo-Moorish, Arabisance style, or Jonnart style. After 1910, the orientalist style with its Moorish and Arabic inspiration proliferated in the Algerian architectural landscape (figure 5). The formulation of this style was based on the imprint of relevant segments in Arab-Islamic architecture, such as horseshoe arches, cupolas, trellises and twin bays (Boutabba 2014); as for the decorative repertoire, it was limited to the juxtaposition of certain architectural elements inspired by Islamic architectural vocabulary. Political and socio-cultural conditions are the principal factors in the appearance of Arabisance architecture.

There were virtually no social housing programs for Muslims and even for Europeans; these programs only became public policy between 1920 and 1939 at the birth of the right of housing (Bouchentouf 2017)

During the first part of the twentieth century, many changes took place in urban space with the introduction of the idea of "modernity", changing the views and ideas of architecture (Hammoudi 2014). Since 1935, the majority of Algerian cities have been characterized by the blossoming of modern architecture. The colonial authority launched a series residential projects, and these modern habitations utilized a modern architecture vocabulary and organization through the simplicity of volumes and balconies. Thus, the interest in the neo-classical style and Orientalist trends waned in favor of buildings adopting a modern vocabulary in residential building design (Bouchentouf 2017). The following table will explain the different types and characteristics of the individual dwellings in this period:

Type of dwelling	Characteristic
Contiguous houses	<i>On the urban scale.</i> This type of housing is concentrated in the city centers and surrounding neighborhoods and is characterized by a regular fabric and the existence of public space; the constructions are similar and aligned. <i>At the architectural scale.</i> The forms of dominant dwellings are rooted in the square and rectangular shape. The exterior appearance is distinguished by large windows and balconies (figure 6). The interior of the house is shaped by a central corridor, which serves the different rooms (3-5 rooms) and a small backyard; some of these houses contain a veranda in the principal facade of the house (figure 7-1).
House type villa	This is a dwelling for the colonial bourgeois class. It is characterized by its location in larger and quiet sites, with a bigger parcel (300 m ² – 700 m ²), courtyard, garden, fountain, and ornamentation of the facades. Some are similar to a western villa type and some are inspired by the <i>Riad</i> house type (<i>traditional palace</i>), which normally had two or more stories around a central courtyard.
Individual type colonial	This type of habitat occupies large communicating parcels. The house consists of two parts: one covered, the main house, the other uncovered, the backyard. The spatial organization follows a central corridor (figure 7). Generally these are composed of four rooms: a reception room whose dimensions are slightly larger than those of the other rooms, two bedrooms, and a kitchen, as well as a toilet block that was generally relegated to the courtyard in the back of the house. The houses are characterized by an extroverted organization of spaces, side gardens or courtyard, and veranda.
Self-built housing	<i>On the urban scale.</i> This type results from a popular production of habitation. This type of home occupies smaller parcels (90m ² - 220m ²), as compared to the colonial houses, indeed-it was inspired in its spatial organization by the traditional house. It is characterized by a dense, sometimes irregular urban fabric, with most of these neighborhoods located on the outskirts of the city. <i>At the architectural scale.</i> In their general forms, the facades do not present a great variety: an introverted organization of spaces around a central courtyard or a corridor, sometimes with the courtyard on the backside of the house, and sometimes the exterior facades are blind or with small windows.

Table 1: The different types and characteristics of the individual dwellings in colonial period.

Architectural Mutations of Individual Houses in the Sahara Desert



Figure 6: Colonial contiguous houses in Biskra (1870) (left). Contiguous houses in Bechar city center (right) (Coll. N. Peyriere).

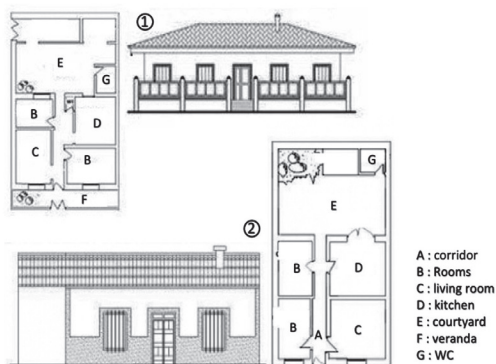


Figure 7: 1) Colonial house, called "veranda home," 2) An aligned colonial house called "home on street" (Hynda Boutabba, 2014; adapted by the authors).

2.3. POST-INDEPENDENCE PHASE: MODERN HOUSE

After independence, Algeria found itself facing a regional imbalance. Algerian society was characterized by the presence of very strong social inequalities and segregations, especially ethnic and cultural inequalities, which were the product of more than 130 years of colonialism (Lalonde 2010). Thanks to the effect of accelerated and uncontrolled urbanization, the old

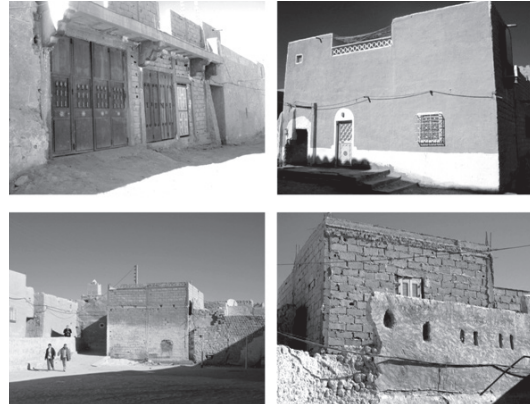


Figure 8: Transformation of the traditional habitation in Timimoun Ksar, Adrar (Otmane & Kouzmine, 2011).

colonial cities and the historic centers of today's Algerian cities offer heterogeneous urban images that are difficult to read and control. According to Kouzmine (2018), since the independence of Algeria in 1962, the exceptional demographic growth that has characterized the Saharan regions is one of the essential markers of the changes in these territories, pointing to lands of exile, in stagnation or even demographic decline. As a result, the average annual growth rate in the Saharan region remained above 3% (Kouzmine and Fontaine 2018). The Saharan territory today has more than 4 million inhabitants. The demographic pressure exerted on the Saharan agglomerations has resulted in sometimes a spectacular extension of the built perimeters and houses. This urban development has at times conflicted with other human uses of space (Kouzmine 2007). From 1962, the official urban and architectural practice was made in direct continuity and an extension of the law and orientations of colonial urbanistic and building regulations. New housing programs are being established, following a linear composition along the main axes, in continuity with the colonial settlements or the form of housing estates.

This period is characterized by the total abandonment of the old Ksour and Kasbah that represents the traditional dwelling, and a movement towards the building of districts in the form of settlements in a checkerboard pattern. In search of modernity, many owners of traditional dwellings completely demolished their homes and replaced them with a more modern house with spaces that meet the demands of time (figure 8). In general, mutations of the individual traditional house have undergone several changes (Otmane and Kouzmine 2011). Sometimes these changes occur through an attempt of restoration and addition of other spaces, according to the user's need, and sometimes through a radical

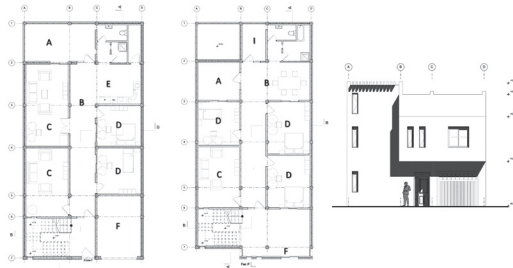


Figure 9: Example of individual housing type in Bechar, Algeria, A (courtyard), B (corridor or hall), C (guest room), D (rooms), E (kitchen), F (balcony). (Author 2019)

transformation. In the new urban fabric (extension of the old Ksar or subdivision), the inhabitant has a plot whose limits are clearly defined, which was not the case in the Ksar, where the houses fit together, or overlap partially. On this parcel, the owner will be able to begin the construction of his house. The building of the house is an individualistic approach that could lead to a consideration of the modern house as no longer responding to the unique model of traditional habitation.

The forms of the modern houses are strongly inspired by the modern architecture imposed during the colonial period. These homes are significantly larger than those of ksar; the footprint can exceed twice the average of ksar houses. The houses are open to the street and move the courtyard to the backside of the house; these are the first fruits of extroversion. The access to the interior is directly off of a corridor or hall, with rectangular rooms. This is joined recently by a new introverted configuration, where access to the interior is through the veranda (Belhadj 2011).

With the liberalization of the market since 1980, individual housing has experienced a significant recovery. In conjunction with the production of an unregulated individual habitat, several important laws were introduced in the 1990s. However, all of this has not been enough to stem the architectural and urban crisis facing Algerian Saharan cities.

The crisis is further exacerbated by several factors, namely the expansion of the built environment, the reduction of financial means, the peculiarities of the Sahara region, and poor organization and management. The unstable economic and political situation in the Algerian Sahara, in addition to the historical impact of colonialism, have led to the deterioration of and problems in the housing sector of the country. Field surveys with the inhabitants have highlighted the contrast between users' strong desire to represent and express what they think is modernity, and the permanence of traditional practices and practices at home. The evolution of the house typology must be explained in the framework of the cultural context,

where the past exemplified by tradition is opposed to the new functionalist character of modernity. Thus, the analysis has differentiated the ideological motivations behind certain architectural modifications concerning the spatial organization, facade, decorations, and daily practices related to the traditional way of life.

2.3.1. SELF-BUILDING HOUSES

The self-building house is now considered the main architectural housing typology and is the most prevalent throughout the desert cities. The spatial organization is through a corridor; rooms are often rectangular and networked around a space that is still called *Ouast Eddar*, which means the center of the house. In addition to its name, the *Ouast Eddar* also keeps its central position in the house, a strategic position with respect to the circulation of the ground floor. On the main facade, we find a garage, which is also often a storage space easily convertible into a shop (figure 9). The facade is generally without any texture (figure 10).

Many similarities exist between the traditional and the modern Saharan house in the allocation of spaces and in their composition, so that many people reappropriate the traditional organization of the house,



Figure 10: Individual modern housing facade in Bechar city, Algeria. (Author 2019)

while formally there is an attempt to use some modern architectural elements, such as the balcony and the garage. This housing type began in the colonial period and often characterizes the suburban neighborhoods of Saharan cities. Unfortunately, there are still many architectural problems in this kind of individual habitation, for example the failure to comply with the laws of building and planning and a facade that does not follow the context or pattern of the city. The production of individual housing in Algeria has always evolved according to political and especially economic data. The policies of the various governments that Algeria has experienced since independence have followed a similar strategy with various social housing programs, in the form of five-year programs, and pursued similar tactics in the different regions of the country, regardless of their different climatic and social characteristics. We should mention that today, the design of dwellings is assured by architectural design offices, which allow the conception of individual dwellings to take on different forms. It becomes obvious that the housing crisis in Algeria and the problems of realization faced by the programs stem from issues of organization, control, competence, and goodwill.

The examination of the different housing types show that the evolution of individual habitat types manifests itself in several aspects:

- Spatial aspects concerning the organization, volume, and shape of rooms.
- Functional or socio-cultural aspects concerning the appearance of new practices.
- Aesthetic aspects concerning the treatment of the facade.

Today, the Saharan cities demonstrate urban chaos, where most house façades are not complete and do not respect the different urban and architectural laws (figure 10). As well, the current individual dwellings today are often not suitable for addressing the climatic, socio-cultural, and architectural aspects of the Saharan region. The distortion of the urban landscape in these areas is due to the contradiction between the desire to represent and express what is believed to be a modern house and the persistence of traditional ways and practices in the home. On the organizational side, the impact is lack of architectural control, as well as non-compliance with the laws and assortment of building codes.

The examination of modern houses mostly reveals the desire for expressing modernity.. This is shown through the residents' attempts to adhere to the traditional spatial organization of the house, at the same time as attempting to keep up with modernity, which often leads to many problems. In this regard, we should note that the use of living space is strongly influenced by culture, which is also largely responsible for many

changes in the built environment (Sriti and Tabet-Aoul 2004) and a determining factor in human habitation, affecting form, function, and organization.

3. THE IMPORTANCE OF CENTRALITY IN THE SAHARAN HOUSES

The essential feature that emerges clearly from the mutations of all the Algerian Saharan houses is the importance of centrality for Saharan society. It is a personalized space, rich with memory and maintaining its role, even if the city and the society face redevelopment and modernization (Benyoucef and Suslova 2019). It is a versatile place that gathers and distributes spaces. It contains almost all the different activities of the house from sleeping, housework, eating, etc.

CONCLUSION

The mutations and transformations in dwelling typology in the Saharan region are manifest especially in the replacement of the traditional housing typology during the colonial period. This new typology appeared in the transformation from the typology of an introverted house type, with a patio and a central space organization, as well as chicane entry, to an extroverted house type, open onto the road with a corridor and a back courtyard. With the disappearance of the chicane entry, *Sguifa*, and the central courtyard (patio), life in the house got a step closer to the street and more open to outside. The *Sguifa* was considered a transition space dialoguing between the two spheres, private and public, as a flexible mode of communication. The *Sguifa* and Patio should take on more importance in future construction, because of the socio-cultural and religious characteristics of Saharan society.

The modern domestic space is still characterized by the significance of the traditional spatial organization. This shows us that the traditional organization of space is still considered very important for Saharan families. The patio houses could be developed in a way that would contribute towards low-energy, climatic adaptability and durability, while furthering socio-cultural values. In developing the design of individual houses in Sahara Desert cities, new Saharan houses must take into account the climatic, sociocultural, and ethnic characteristics of the Saharan society, including other important factors such as the family events, the hospitality characteristic of the Saharan family (visits of many relatives or friends), and guest rooms (the separation between the family area and guest area is considered very important). Taking into account the socio-cultural factors influencing Saharan family's behavior, the variety of events and religious affiliation, it is very important to avoid the different changes that an individual makes in their houses to suit their needs.

REFERENCES

- Aleth, P. 1994. *Architecture et urbanisme en Algérie. D'une rive à l'autre (1830-1962)*, revue du monde musulman et de la Méditerranée, no. 73-74: 121-136.
- Badr-Eddine, Y. 2013. "Mutation de l'habitat: normalisation technique et implications sociales (Dans les villes du Sud-ouest algérien)." *Le Sociographe* 4, no. 44: 45-52.
- Belhadj, N. 2011. "L'habitat traditionnel a Oued Souf." Accessed November 2020. http://www.rehabimed.net/wp-content/uploads/2011/02/160_ARG_Nabila%20Belhadj.pdf
- Benzaoui, A. 2013. *Le Processus de Creation d'un Habitat Individuel de Qualite, Cas de la Ville d'Ain Beida*, these de magistère, université Badji Mokhtar.
- Benyoucef, M.Y. and A.D. Razin. 2018. "Consideration of climatic conditions in the design of dwellings in the Sahara Desert" *RUDN Journal of Engineering Researches* 19, no. 4: 471- 481.
- Benyoucef, M. Y. and O. Suslova. 2019. "Typology and Architectural Features of Traditional Dwellings in the Great Sahara (Case of Patio and Underground Houses)." *Architecture and Modern Information Technologies* 4, no. 49: 98-107.
- Boudiaf, B. 2003. "Les trois âges de la ville algérienne." In *Villes en Parallèle*, no. 36-37: 28-47.
- Boutabba, H., A. Farhi, and M. Mili. 2014. "Le patrimoine architectural colonial dans la région du Hodna, un héritage en voie de disparition. Cas de la ville de M'sila Algérie." *CNRS editions*: 269-295.
- Bouchentouf, N.M. 2017. *Cours d'histoire et de politique de l'habitat en Algérie*, Département d'architecture, FAGC, USTO, 30-37.
- Bousquet, C. 1986. *L'habitat Mozabite Au M'zab*, éditions du CNRS, Annuaire de l'Afrique du Nord, Tome XXV: 257-269.
- Chehma, A. 2011. *Le Sahara en Algerie, situation et defis*, CMEP Tassili, N° 09 MDU 754, université Kasdi Merbah.
- Dabaieh, M. 2011. *A Future for the Past of Desert Vernacular Architecture*. Lund: Media-Tryck; Lund University.
- Francesca, D.F. 2006. *Traditional architecture in the Dakhleh Oasis, Egypt: space, form and building systems*, PLEA2006, the 23rd Conference on Passive and Low Energy Architecture, Geneva, Switzerland.
- Hadjilah, A. 2016. *L'architecture des premières maisons européennes d'Alger 1830-1865*, École Polytechnique d'architecture et d'urbanisme (EPAU), Vol. 5, issue 1: 8-23
- Hamouda, A., Abdou, S. 2013. *Approche d'une analyse syntaxique de l'habitat rural, cas d'El Kantara*, *Courrier du Savoir*, no. 16: 27-36.
- Hammoudi, A. 2014. *Le patrimoine ksourien, mutation et devenir. Le cas du Zab El Gherbi-Tolga*, diplôme de Magister, Université Mohamed Khider, Biskra.
- Hameidi, Iman. 2015. *Introduction d'une nouvelle formule de logement "l'auto-construction"*. URL: <http://www.pme-dz.com/introduction-dune-nouvelle-formule-de-logement-lauto-construction>
- Kouzmine, Y. 2007. *Dynamiques et mutations territoriales du Sahara Algerien, vers de nouvelles approches fondées sur l'observation*, Université de Franche-Comté, 17.
- Kouzmine, Y. and J. Fontaine. 2018. *Démographie et urbanisation au Sahara Algérien à l'aube du XXIe siècle*, N°30, les cahiers d'EMAM.
- Lalonde, M. 2010. *La crise du logement en Algérie: des politiques d'urbanisme mésadaptées*, Université de Montréal, 29.
- Lewis, L.A. and L. Berry. 1988. *African Environments and Resources*. London: Routledge.
- Nefidi, H., S. Oukaci, A.E.K. Hamid, and D. Semmar. 2017. *Etude thermique d'une maison traditionnelle en Algérie (cas de Oued Souf)*. CIER, PET, Vol. 3: 19-23.
- Sriti, L., A. Belakehal, K. Boussora, and A.Z. Saouli. 2002. "Le damier colonial de Biskra ou l'histoire de la marginalisation d'un centre-ville." *Courrier du savoir scientifique et technologique* 6, no. 02 (Juin): 53-39.
- Sriti, L. and K. Tabet-Aoul. 2004. "Evolution des modeles d'habitat et appropriation de l'espace le cas de l'architecture domestique." *Les ziban*, *courrier du savoir*, no. 05: 23-30.
- Tayeb, O. and Y. Kouzmine. 2011. *Timimoun, évolution et enjeux actuels d'une oasis saharienne algérienne*, *Insaniyat*, no. 51-52: 165-183.

CHANGING WATERSCAPES: The Dichotomy of Development and Water Management Surrounding the East Calcutta Wetlands since the British-colonial Era

Abhinandan Bera & Hong Wu
Pennsylvania State University

Abstract: The deltaic region of Bengal is known for its riverine networks and fertile soil. The capital of former British-India, Calcutta, was a swampy region with small canals connecting the land with the river Hooghly in the west and to the saltwater lakes in the east, now known as the East Calcutta Wetlands (ECW). The eastern canals carry the city's wastewater to the ECW for treatment using sewage-fed fisheries and farmlands and then released it into the Bay of Bengal via the Kulti River. In the early British colonial period, the salt lakes were depicted as hindrance to the health and well-being of the city's inhabitants because of high mortality in the region, presumably caused by miasmatic diseases. Part of these marshes, the ECW now acts as a giant sink for this dense post-colonial urban settlement, helping to drain the land, providing food and employment, and saving costs for artificial wastewater treatment plant. This hydrologic system is now at risk due to encroachment from real-estate development and pollution in the adjoining canals, posing an immense threat to this critical human-water relationship. In this paper, we examine the dichotomy of urban development and water management since the colonial era to assess the temporal nature of the human-water negotiations behind the changing waterscapes.

Keywords: Colonial, wetlands, water, urban, Calcutta, human-water relationship

INTRODUCTION

The present city of Calcutta, India, was once a marshland protected by a levee from the River Hooghly. The land gradually sloped down from this levee in the west towards the saltwater lakes in the east, now known as the East Calcutta Wetlands¹ (ECW), recognized by the Ramsar Convention in 2002 as one of international importance (Ramsar 2002). Calcutta, being relatively flat (Richards 1914) and swampy, has been difficult to "tame" by the British in the colonial era. Institutional reports² on improving sanitation in the city spoke of the harrowing conditions created in the town due to poor drainage, flooding, and consequent health issues, especially from water-borne diseases. Natural canals weaving through this landscape were studied, experimented on³, and modified to facilitate drainage and navigation in the region, addressing tidal fluctuations and problems with excessive siltation (Apjohn 1895). The canals in Calcutta now carry the city's wastewater to the ECW, where it is treated using fisheries and agricultural lands, saving the expenses of artificial wastewater treatment and providing local employment opportunities (Ghosh and Sen 1987). This unique system is under threat of encroachment and pollution from domestic and industrial sources, which have brought doubt over the water management strategies of this city of five million.

In this research, we examine a historical conflict between urban development and waterscapes in the

Calcutta region, since the early days of the British colonial era. After scrutinizing British water management practices as the West's ways of countering the East's waters, we discuss the water woes of this city in colonial and post-colonial periods. This paper serves as an exploration of human-water negotiations that have historically prioritized urban development over sustainable management of water resources. Supported by findings from ethnographic fieldwork, we establish the problems currently being faced by the city's waterscape and identify present actions and consequences as a legacy of colonial water management, through a study of archival reports, journals, and planning documents.

1. URBAN DEVELOPMENT IN CALCUTTA

1.1. BEFORE BRITISH COLONIALISM IN CALCUTTA

Europeans had long been aware of the rich prospects that trade with the Indian subcontinent would bring into the Ganga-Brahmaputra deltaic region of Bengal, especially with goods like spices, textiles, and saltpeter (Cotton 1907). This attracted the Europeans—Portuguese, French, Dutch and finally, the British, to this land (Nair 1986). Riparian corridors of trade and transportation were crucial for this deltaic mercantile port-city and by connection, its hinterlands (Tan 2007). Trade, therefore, was serious business at the estuarine lowlands of Bengal, spread along the length of the River

Hooghly. To take advantage of Portuguese maritime trade, weavers settled across the river in a town called Sutanuti (Datta 2012, 12). Owing to the marshy nature of this landscape, the villages of Sutanuti, Kalikata, and Gobindapur never undertook conscious town planning endeavors, until the British excavated canals to drain the place and built roads for transit.

1.2. THE EARLY COLONIAL PERIOD IN CALCUTTA

The city of Calcutta started to gain importance as a trading post for the British after they defeated the Nawab of Bengal in the Battle of Plassey in 1757 and developed the land around Fort William. With already existing Indian settlements in the north of Fort William, the British administrators decided to expand their settlements to the east and the south of the central business district (Hornsby 1997). The southern part of the city was more pleasant owing to the cool prevailing winds from the Bay of Bengal. The expansion of Calcutta, however, highlighted racial, ethnic, and economic divisions in land use. Most port cities in India had an area where local inhabitants settled, known as the Black town and a European enclave known as the White Town (S. Chattopadhyay 2000). Calcutta, however, showed a third category of town known as the Grey town, which housed foreign populations like the Portuguese, Armenians, Greeks, and Jews (Hornsby 1997). The formation of white, black, and grey towns inside Calcutta developed spatial identities that remain present today.

In the earliest days of the East India Company, the city of Calcutta lacked any infrastructure deemed suitable to British India's first capital (Datta 2012). One of the first measures by the British, therefore, was to make Calcutta suitable for development by taming its marshy land and jungles. According to Chaudhuri (1990), there was no mention of an existing network of roads in Calcutta before the British arrived. Thoroughfares did not reflect any planned layout and did not have any name; they were generally referred to by people as "the road to the east", or "the road towards the river". In 1766, J. Fortnam, a Civil Architect for the British Administration, proposed new roads, buildings, and watercourses for Calcutta. His proposal mentioned two watercourses in Shambazar Road, one watercourse in Chitpur Road, and one watercourse in the Chowringhee Road, for 125 rupees each. Besides, he also proposed the construction of twenty eight small bridges and watercourses in and around Calcutta for a sum of 3000 rupees. In 1749, the government ordered drains "to be surveyed to make the settlement sweet and wholesome" (Sen 2000). A network of planned roads can be seen in a map (figure 1) developed by A. Upjohn from the survey in 1792-

93, published in 1794 (Chaudhuri 1990; Kundu and Nag 1990). Since then, the Lottery Committee and the Fever Hospital Committee continued developing the city of Calcutta by building roads, sewers, and canals for drainage. By the end of the nineteenth century, plague-stricken Calcutta needed a strategic intervention to improve the conditions of the city, especially of sanitation and transit systems (Richards 1914).

1.3. IMPROVEMENT AS A STRATEGY FOR URBAN DEVELOPMENT

The Calcutta Improvement Act of 1911 called for various improvement measures to be undertaken by the Calcutta Improvement Trust (CIT). Edwin Percy Richards, a British engineer examined the trust's work and wrote the *Report on the Condition, Improvement and Town Planning of the City of Calcutta and Contiguous Areas* (1914). It had been recognized as "the first systematic attempt to translate European planning ideas into a colonial context" (Home 2016). It poured insight into Calcutta's critical issues and its future growth, such as unhygienic conditions in slums, the need for transit systems to connect areas within the city and to its suburbs, and poor drainage, which remained relevant to this day. Inspired by the Glasgow Improvement Model, similar plans were developed for other Indian colonial port cities like Madras, Bombay, and Singapore (Datta 2012).

The *improvement* plans proposed by the CIT broadly addressed two issues: transit and sanitation. These improvement measures, popularized as necessary changes on the urban landscape for its own good, were as detrimental to the urban poor then as the developmental plans are now. To implement these changes, the social identity of the people was questioned, festivals and cultural gatherings were prohibited; housing for the poor was neglected. Richards had expressed his discontent regarding the poor capacity of the city's mass transit system (Richards 1914), noting that this would amount to a larger problem in the future.

"Improvement" plans further contributed to growing economic inequity and socio-spatial segregation, adding to the existing social turmoil. The use of urban public spaces was strictly limited to the Europeans and the Indian elites, who were unsure whether to prioritize equality over improved luxurious facilities in the city (Datta 2012). An article in the *Times of India*, a popular newspaper, spoke of the "urban improvement" in Calcutta as a movement that had placed Calcutta on the maps. While mentioning that the urban poor had been forcibly removed from their dwellings as a measure of improvement, the article went on to say that "the [Calcutta Improvement] Trust is entitled to gratitude for the success with which it

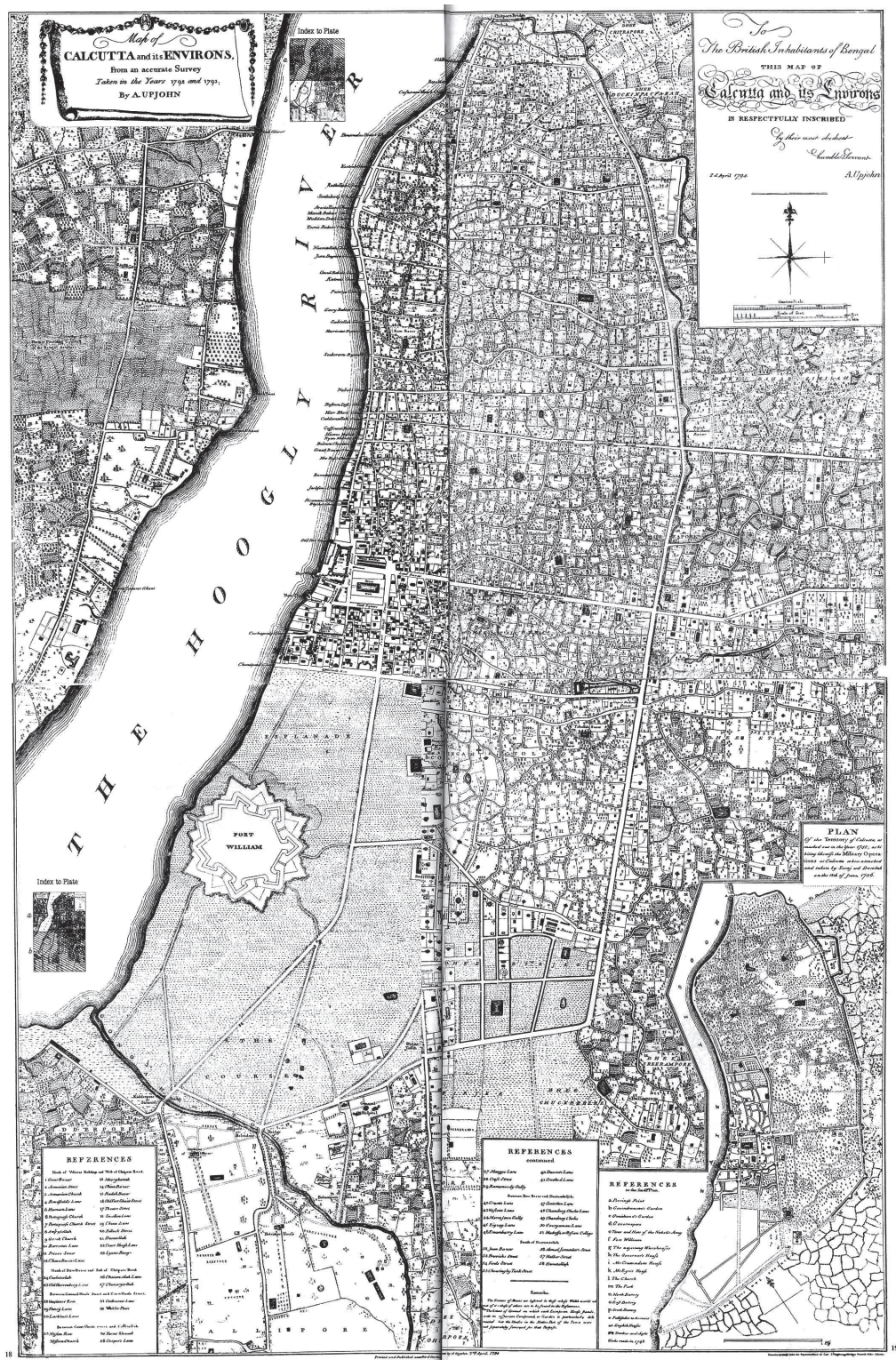


Figure 1: 1792 Map by Upjohn showing Fort William and roads of Calcutta. (Kundu and Nag 1990, 16-19)

has added to the amenities as well as the beauty of the premier city of India" (Times of India 1929). The article boasted an overflow of expenses towards improvement measures, but failed to reveal the increase in taxes and revenue that were directed towards providing additional funding for the Trust (Times of India 1929; Bompas 1927). Along with roads and public parks, the late nineteenth century also saw considerable development of canals for drainage, navigation, and irrigation. Canals were experimented on to tackle silt deposition and steady flow for navigation (Apjohn 1895). However, beyond urban development, water emerged as an instrument for socio-political change (Bakker 2012).

2. THE WEST'S WAY OF MANAGING THE EAST'S WATERS

The practice of finding the sacrificial lamb in waterscapes that gained momentum in the post-colonial era had been fueled by two centuries of imposition of western ways to manage water in the East. Demanding a higher water flow for increased productivity, the British uprooted traditional water management in rural India, and employed perennial irrigation through canals in the Punjab area (Agnihotri 1996). Gilmartin (1994) argued that control of irrigation was reflected upon as the hinge between the power of local community and that of the state. He explained how, in the 1850s, the British abolished the *chher* labor system in the Sind region, that employed unpaid local villages to clear off the silt in irrigation canals for "effective state management of canals" (Gilmartin 1994, 1134). Similar to management of other natural resources, including forests and farmlands, British intervention in water-management reflected "a distinct hydraulic paradigm", which D'Souza has addressed under the broader theme of "colonial hydrology" (2006, 621). He argued that the colonizers have historically imposed the western way of managing water by "fundamentally realigning land and water in new sets of social, political and ecological relationships." (D'Souza 2006, 625).

Colonial decisions on water endowment, much like the rest of their natural resource management approaches, predominantly saw the Indian subcontinent as a "seemingly immeasurable extent of natural" (Whitcombe 1972). To ensure the "productive control of natural resources," the British took to Imperial Science (Gilmartin 1994) and engineered solutions, where traditional Indian ways of water management were quickly shifted to the backseat, stamped "native" and "unscientific" (Agnihotri 1996, 39). What has been termed by D'Souza (2006) as "colonial hydrology", a grand scenario of shifting relationships between people and water was justified by the British administrators as "improving" upon

the local knowledge. Colonial irrigation systems in the canals of Punjab led to adverse ecological conditions such as waterlogging and salinization as well as impacted the community (Agnihotri 1996, 37). Elizabeth Whitcombe's *Agrarian Conditions in Northern India* (1972) adds to the colonizers' impact on instruments of traditional water management including wells. In contrast, Ian Stone's monograph titled *Canal Irrigation in British India* (2002) argues that the British interventions in water management were, in fact, a crucial step towards the adaptation of new technologies by the peasants to maximize production, implemented with a view of economic dynamism.

3. WATER WOES IN CALCUTTA

3.1. CANALS

In the early settlements of Calcutta, not much attention was paid to the building of roads or drains by the Indians. Early roads were known to have shallow channels flanking the roads to take care of drainage, especially during the monsoon seasons. Poor drainage and sanitation increased the risks of water-borne diseases, making the region unsuitable for healthy living (Sen 2000). The roads carried dead bodies of animals, as well as human and cattle sewage in open drains which opened into the River Hooghly. However, these roads and the adjacent canals were identified by the British as unhygienic, and therefore, the land adjacent to this region was not suitable for habitation (Chaudhuri 1990). This laid the ground for the revival of the roads and drainage networks, which were guided by reasons of health and a sense of security.

The Maratha Ditch, which essentially separated the British settlements from the rest of the city (Sreemani 1998), was excavated in the 1740s from an existing canal presently known as the Circular Canal. The Circular Canal continued to the southern part of the city. However, this canal was initially excavated to keep the Maratha rulers away (Richards 1914) and was later critical in shaping the outer periphery of Calcutta (Sreemani 1998). The Calcutta port is situated in the southern part of the city, which is not highly silted and therefore easily accessible for transportation and shipping. The port is close to another existing canal known as the *Adi Ganga*, which was excavated by a Major William Tolly of the British East India Company in 1775 and opened to the public in 1777 (Bhattacharjee 2014). The *Adi Ganga* was leased to Major Tolly for 12 years for collecting revenue on the goods transported (Biswas 2001), and later came to be known as Tolly Nullah.⁴

Besides navigation, these canals also facilitated other urban systems like drainage and sanitation.

The need for a comprehensive sewer network was evident in both Mr. Clark's Drainage Scheme (1855) and the Cowie Report on draining the city of Calcutta (1857). However, it was debated whether the construction of a vast network would be disruptive to the residents' way of life. Therefore, it was decided that the network of sewers would be used as a guide for building new roads (Beverley and Lidderdale 1885). This would not only allow the engineers to properly drain the city but would also add to the cost of disruptions caused to the residents.

The British development of Calcutta induced the growth of many industries in the outskirts of the city. This included the development of leather industries in the Entali area (Chaudhuri 1990). Presently, small-scale industries and informal settlements flank canals carrying the wastewater out of the city and use them as a disposal ground for untreated wastes. This renders the canals visibly polluted (Ramsar 2002) and raise concerns for the water that enters the ECW. Untreated industrial effluents find their way to the ECW which contaminate the wetland's water as well as the fish produced as part of a resource recovery system (Roy et al. 2011).

3.2. SALTWATER MARSHES

The saltwater marshes were situated at the lowest elevation of the city and drained the water to the Bay of Bengal through the river Kulti and then, Bidyadhari (Ghosh and Sen 1987). These rivers continued further east to another network of canals which aided navigation and was crucial to thriving trade and commerce in the region connecting Assam and parts of present-day Bangladesh (Inglis 1909). A substantial controversy surrounded these saltwater marshes, recognized as tidal wetlands, which cause the water accumulated into the wetlands from the city, to drain into the eastern canals and ultimately meet the Bay of Bengal in the south. These wetlands have always been understood as a nuisance owing to their swampy nature and standing water, which led to the breeding of mosquitoes, and have been considered for reclamation for other uses, since the early nineteenth century (Smith 1869). Although these wetlands were seen as the city's "limit of building-land" (Richards 1914, xiv), a letter from the Honorary Secretary of the Anglo-Indian Association to C H Bompas (then Chairman of the CIT) talked about expanding the city to the east by obliterating the saltwater lakes:

Their (the salt lakes') presence ... is a perpetual menace to its (the city's) health and unreasonable restriction to its natural expansion. To recover these ... and put them to profitable use should be made the aim of Government... It cannot possibly be a task beyond

engineering skill when examples exist all over the world of vast areas ... being rescued from swamps, and even from the sea, to be put under the plough after a few years. T.A. Milne, Honorary Secretary, The Anglo-Indian Association, Calcutta (CIT 1913, 31). Source: British Library Archives of India Office Records.

The marshes to the east of Calcutta have been discussed repeatedly concerning miasmatic diseases (Hamilton 1727; Martin 1837), and their role in the poor sanitary condition of the city (Smith 1869). Drainage has always been a problem for the city and its inhabitants, evident in increased mortality due to water-borne diseases (Clark 1855). There have been several attempts to solve the drainage problem, of which the canals were a crucial part, especially the seasonal flooding during the monsoon months. While the Circular canal in the north served as a military measure against the Maratha rulers, the Tolly's Nullah in the south provided a better connection to the River Hooghly for navigation purposes. However, the canals to the east of the city, including the Beliaghata Canal and the New Cut Canal have found special mention as conduits for the city's stormwater in the comprehensive documentation by W. A. Inglis in his book titled *The Canals and Flood Banks of Bengal* (1909). They hold special relevance to the ecology of the city, due to their connectivity and proximity to the Ramsar-recognized Wetlands and the Sundarbans (A UNESCO World Heritage Site - 1997) further south of the city.

After India's independence from the British rule, from 1962-67, a part of these saltwater marshes, now recognized as the East Calcutta Wetlands, was filled up to accommodate the growing population of Calcutta. The township that replaced these marshes was named Salt Lake City (H. Chattopadhyay 1990).

3.3. THE EAST CALCUTTA WETLANDS (ECW)

Salt marshes represent a complex structure of flora, fauna, and microbes, characterized by frequently changing salinity, level of water, and seasonal temperature variation. The stability of such marshes depends on two primary characteristics: 1) sediment deposition, and 2) submergence of marsh due to the inflow of saline water (Mitsch and Gosselink 2000). The saltwater marshes changed to freshwater lakes when the River Bidyadhari dried up in 1928 and stopped the inflow of saline water from the Bay of Bengal (Ghosh and Sen 1987, 222). The marshes used to harbor saltwater fisheries, which changed to sewage-fed fisheries in 1930, and the wastewater began to be carried away by the River Kulti (Ghosh and Sen 1987, 222). With a lower inflow of saline water and more inflow of freshwater from the city, the salinity of the wetlands decreased, making it possible

to cultivate paddy and vegetables (Mukherjee 2015). The wastewater from Calcutta now flows through the eastern canals into the ECW, where the sewage serves as nutrients for fish production and agricultural fields (Dey and Banerjee 2013). The ECW consists of a core region with fishponds, where wastewater is treated and fishing is practiced, garbage-farming region for seasonal vegetables using wastewater for irrigation, and a vast paddy farming region (Furedy and Ghosh 1984). Through its resource recovery system, using farming and aquaculture, the ECW also acts as a significant social contributor by providing food, sanitation, and livelihood.

3.3.1. PRESENT-DAY WATER WOES

The ECW comprises several small and large fishponds that are either registered with the government or privately owned. To understand the present issues of drainage and water resources management, we conducted interviews amongst government officials and institutions about the historical evolution of water management and the current dangers faced by these wetlands. We also interviewed 40 fishermen and owners from three of these fisheries, ages ranging from 24 to 60, to learn about the activities involved that make this a successful resource recovery system, and the factors which impact their sustenance and the quality of fish production. Open-ended interviews with these fishermen and officials in managing institutions revealed the following findings:

1. Fish production in the ECW is largely impacted due to transit corridor runoff and decreasing organic matter in the wastewater because of changing land use along the canals. Due to the lack of organic matter in the wastewater, many fisheries depend on artificial feed to keep up with the production and meet the demand for fish in the city. On the other hand, the canals flanked by small industries, commercial establishments, and leather tanneries have historically polluted the water carried away from the city.
2. The depth of the ponds has reduced at some places to less than two feet due to the inflow of silt through the canals, which deters the steady production of fish. Some of the government registered fisheries have been excavated to increase the depth, with the excavated earth used to increase the peripheral levee height. Most fisheries cannot afford to stop production for the duration of this crucial process of revival and therefore continue fishing with these limitations. The fisheries being the only source of income makes it difficult for resident workers to make ends meet daily.
3. Officials in government institutions in charge of addressing encroachment issues have shed light on factors affecting the function of this resource recovery system and complexities associated with underlying political and social processes, the discussion of which is beyond the scope of this paper. But we have noted these findings as crucial interactions between the resources and their users, providing insights on social and cultural capital, and their vitality in managing these ecological resources.

The lack of awareness and effort to improve canals and flanking land further complicates these problems, leading to a gap in simultaneous prioritization and integration of social and ecological processes. Connection with the ECW makes the assessment of drainage issues and the understanding of relevant hydrological systems and ecological functions more difficult, due to the lack of a comprehensive, integrated approach in addressing social and ecological aspects.

CONCLUSION

The East Calcutta Wetlands form a crucial part of the regional hydrological system, which includes the canals, the River Hooghly, as well as the city's connection to the Bay of Bengal in the Sundarbans deltaic region that hosts a large mangrove population and acts as a reserve for the endangered Royal Bengal Tiger (Chundawat, Khan, and Mallon 2011). As a resource recovery system, the wetlands use the city's wastewater for its diverse uses in sewage-fed fisheries and farmlands. This process, recognized by the Ramsar Convention for its uniqueness, takes place in the 12,500 hectares of wetlands, out of which fishponds cover about 4000 hectares. While the wetlands are not efficient in groundwater recharge, they are useful in trapping sediments and retaining nutrients through an aquatic food chain (Ramsar 2002). Many years ago, a concern was raised by David Cowie (1857) in the Drainage Report of Calcutta regarding whether the practice of converting sewage into deodorized manure would be accepted in India. The report also questioned whether this would, in the end, turn out to be profitable. Today, the ECW helps drain the city, treats its wastewater, and generates crucial resources for its inhabitants (Ghosh 2014).

This historical study of the city's human-water negotiations reflects the strenuous relationship between the place, its people, and governing institutions. In the waterscape of Calcutta and surrounding regions, spatial decisions on natural systems were based on social drivers, and the importance of water resources would yet be reflected in urban planning initiatives.

This trend continued in the post-colonial era, when a portion of the eastern wetlands draining the city's wastewater would be filled up and "reclaimed" for urban development. The practice of de-prioritizing water resources over real estate and "developmental" activities continues to threaten Calcutta's waterscape. Without a more involved strategy to better understand the social capital of ecological resources, urban development and water management will remain a dichotomy and stray further from the necessary integration of social and ecological systems, which is the need of the hour.

ACKNOWLEDGEMENT

We thank Deryck Holdsworth, Professor Emeritus of Geography, Charles Andrew Cole, Associate

Professor, Mallika Bose, Professor in the department of Landscape Architecture, and Leif Jensen, Distinguished Professor of Rural Sociology and Demography at the Pennsylvania State University for their support and encouragement. We would also like to extend our gratitude to the organizers of the Ph.D. symposium at the Georgia Institute of Technology.

This research is funded by the Ecology plus Design Center, the Alma Heinz and August Louis Pohland Graduate Fellowship, and the Stuckeman School of Architecture and Landscape Architecture at the Pennsylvania State University. The Office for Research Protection at Penn State has examined this research (STUDY00010199) and deemed it exempt from requiring a formal IRB review.

ENDNOTES

- 1 The name "Calcutta" was changed to "Kolkata" in 2001 (Datta 2012). The swamps towards the east of the city mentioned in Richards's Report (Richards 1914) were later recognized by the Ramsar Convention as the "East Calcutta Wetlands." We use the name Calcutta throughout this paper for consistency.
- 2 Examples of such reports include *Certain Matters Connected to the Sanitation of the Town of Calcutta* (Beverley and Lidderdale 1885), *A Report on the Drainage of Calcutta* (Clark 1855), and *Report of the Committee on the Drainage of Calcutta* (Cowie 1857), and *Report, by Request of the Trust, on the Condition, Improvement and Town Planning of the City of Calcutta and Contiguous Areas* (Richards 1914).
- 3 A. J. Apjohn, then Chief Engineer for the Calcutta Port Trust and Fellow and Faculty of Engineering at the University of Calcutta delivered *Two lectures on Navigation Canals in India* at the Sibpur Civil Engineering College (now known as the Indian Institute of Engineering, Science and Technology, Shibpur) on 27th March and 9th April 1895. Here, he built on several experiments conducted on the River Hooghly, the Orissa Coast Canal, the Tolly Nullah and the River Bhageratti to understand the nature of the waterways in this region and propose design solutions such as sluices, lock gates and silt traps, to make them navigable (Apjohn 1895).
- 4 The word "Nullah" was derived from a local Bengali word which meant water channels (Yule and Burnell 1886).

REFERENCES

- Agnihotri, Indu. 1996. "Ecology, Land Use and Colonisation: The Canal Colonies of Punjab." *The Indian Economic & Social History Review* 33, no. 1: 37-58.
- Apjohn, J. H. 1895. *Navigation Canals in India*. Calcutta: Bengal Secretariat Press.
- Bakker, Karen. 2012. "Water: Political, Biopolitical, Material." *Social Studies of Science* 42, no. 4: 616-23.
- Beverley, H., and R. Lidderdale. 1885. *Certain Matters Connected to the Sanitation of the Town of Calcutta*. Calcutta: Bengal Secretariat Press.
- Bhattacharjee, Chandrani. 2014. "Canals and its relevance to the Kolkata Megacity." *Abhinav National Monthly Refereed Journal of Research in Arts & Education* 3 (5): 20-24.
- Biswas, K. R. 2001. *Rivers of Bengal: A Compilation*. Calcutta: West Bengal District Gazetteers, Higher Education Department, Government of West Bengal.
- Bompas, C. H. 1927. "The Work of The Calcutta Improvement Trust." *Journal of the Royal Society of Arts* 75 (3868): 199-219.
- Chattopadhyay, H. 1990. *From Marsh to Township East of Calcutta: A Tale of Salt Water Lake and Salt Lake*. Calcutta: KP Bagchi.
- Chattopadhyay, Swati. 2000. "Blurring Boundaries: The Limits of 'White Town' in Colonial Calcutta," *Journal of the Society of Architectural Historians*, 59(2), pp.154-179.
- Chaudhuri, Sukanta. 1990. *Calcutta, the Living City (Vol. 1 & 2)*. New York;Calcutta; Oxford University Press.
- Chundawat, R. S., J.A. Khan, and D.P Mallon. 2011. "Panthera Tigris Ssp . Tigris , Bengal Tiger." *The IUCN Red List of Threatened Species* 2011: 8235. <https://doi.org/T136899A4348945>.
- CIT. 1913. *Annual Report on the Operations of the Calcutta Improvement Trust for the Year 1912-1913*. Calcutta: Calcutta Improvement Trust.
- Clark, W. 1855. *A Report on the Drainage of Calcutta*. Calcutta: Edmund D'Cruz and Co.

Changing Waterscapes

- Cotton, H. E. A. 1907. *Calcutta Old and New*. Calcutta: W. Newman & Co.
- CCowie, David. 1857. *Report of the Committee on the Drainage of Calcutta*. Calcutta: "Calcutta Gazette" Office.
- D'Souza, Rohan. 2006. "Water in British India: The Making of a 'Colonial Hydrology.'" *History Compass* 4, no. 4: 621-628. <https://doi.org/10.1111/j.1478-0542.2006.00336.x>.
- Datta, Partho. 2012. *Planning the City: Urbanization and Reform in Calcutta, c. 1800 - c. 1940*. New Delhi: Tulika Books.
- Dey, Debanjana, and Sarmila Banerjee. 2013. "Ecosystem and Livelihood Support: The Story of East Kolkata Wetlands." *Environment and Urbanization Asia* 4, no. 2: 325-337. <https://doi.org/10.1177/0975425313511158>.
- Fryer, John. 1861. "1698. A New Account of East-India and Persia." *Eight Letters. Being Nine Years Travels, Begun 1672. And Finished 1681*.
- Furedy, Christine, and Dhrubajyoti Ghosh. 1984. "Resource-Conserving Traditions and Waste Disposal: The Garbage Farms and Sewage-Fed Fisheries of Calcutta." *Conservation and Recycling* 7 no. 2-4: 159-165. [https://doi.org/10.1016/0361-3658\(84\)90014-6](https://doi.org/10.1016/0361-3658(84)90014-6).
- Ghosh, Dhrubajyoti. 2014. *Ecosystem Management: Towards Merging Theory and Practice*. New Delhi: Nimby Books.
- Ghosh, Dhrubajyoti, and Susmita Sen. 1987. "Ecological History of Calcutta's Wetland Conversion." *Environmental Conservation* 14, no. 3: 219-226. <https://doi.org/10.1017/S0376892900016416>.
- Gilmartin, David. 1994. "Scientific Empire and Imperial Science: Colonialism and Irrigation Technology in the Indus Basin." *The Journal of Asian Studies* 53, no. 4: 1127-49.
- Hamilton, Alexander. 1727. *A New Account of the East Indies (Vol. 1 & 2)*. Edinburgh: John Mosman.
- Home, Robert. 2016. "British Colonial Civic Improvement in the Early Twentieth Century: E. P. Richards in Madras, Calcutta, and Singapore." *Planning Perspectives* 3, no. 4: 635-644. <https://doi.org/10.1080/02665433.2016.1185961>.
- Hornsby, Stephen J. 1997. "Discovering the Mercantile City in South Asia: The Example of Early Nineteenth-Century Calcutta." *Journal of Historical Geography* 23, no. 2: 135-50.
- Inglis, W. A. 1909. *The Canals and Flood Banks of Bengal*. Calcutta: Bengal Secretariat Press.
- Kundu, A. K., and P. Nag. 1990. *Atlas of the City of Calcutta and Its Environs*. National Atlas & Thematic Mapping Organisation, Ministry of Science and Technology, Government of India.
- Martin, Sir James Ranald. 1837. *Notes on the Medical Topography of Calcutta*. GH Huttman, Bengal Military Orphan Press.
- Mitsch, W J, and J G Gosselink. 2000. *Wetlands (3rd Edn)*. Wetlands. New York: Wiley.
- Mukherjee, Jenia. 2015. "Beyond the Urban: Rethinking Urban Ecology Using Kolkata as a Case Study." *International Journal of Urban Sustainable Development* 7, no. 2: 131-146. <https://doi.org/10.1080/19463138.2015.1011160>.
- Nair, P. Thankappan. 1986. *Calcutta in the 17th Century*. Calcutta: Firma KLM.
- Ramsar. 2002. "Information Sheet on Ramsar Wetlands (RIS)." *Ramsar Convention*. <https://rsis Ramsar.org/RISapp/files/RISrep/IN1208RIS.pdf>
- Richards, E P. 1914. *Report, by Request of the Trust, on the Condition, Improvement and Town Planning of the City of Calcutta and Contiguous Areas*. Hertfordshire: Jennings & Bewley.
- Roy, Utpal Singha, Buddhadeb Chattopadhyay, Siddhartha Datta, and Subhra Kumar Mukhopadhyay. 2011. "Metallothionein as a Biomarker to Assess the Effects of Pollution on Indian Major Carp Species from Wastewater-Fed Fishponds of East Calcutta Wetlands (a Ramsar Site)." *Environmental Research, Engineering and Management* 58, no. 4: 10-17.
- Sen, Ranjit. 2000. *A Stagnating City: Calcutta in the Eighteenth Century*. Calcutta: Institute of Historical Studies.
- Smith, David Boyes. 1869. *Report on the Drainage and Conservancy of Calcutta*. Calcutta: Bengal Secretariat Press.
- Sreemani, Soumitra. 1998. "Problems of Writing a History of Calcutta of the late 18th Century." In *Proceedings of the Indian History Congress* 59: 579-86.
- Stone, Ian. 2002. *Canal Irrigation in British India: Perspectives on Technological Change in a Peasant Economy*. Vol. 29. Cambridge: Cambridge University Press.
- Tan, Tai-Yong Yong. 2007. "Port Cities and Hinterlands: A Comparative Study of Singapore and Calcutta." *Political Geography* 26, no. 7: 851-65. <https://doi.org/10.1016/j.polgeo.2007.06.008>.
- Times of India (OUR, O.C.). 1929. *Calcutta Improvement Trust: How the City Has Changed the Progress of a Tremendous Task*. Mumbai: Times of India.
- Whitcombe, Elizabeth. 1972. *Agrarian Conditions in Northern India*. Berkeley: University of California Press.
- Yule, H., and A. C. Burnell. 1886. *Hobson-Jobson: Being a Glossary of Anglo-Indian Colloquial Words and Phrases, and of Kindred Terms: Etymological, Historical, Geographical, and Discursive*. London: J. Murray.

GRAPHS, SETS AND COVERS; SEEING WHAT HAS ALWAYS BEEN THERE: Finding Common Ground between BIM Applications and their Users

Mehmet Sinan Bermek
Georgia Institute of Technology

Abstract: Building Information Models and Process Diagrams rely on data modeling types that can vary. By definition, information contained in the very common Relational Model Databases (RMDDB) can be contained in the GDBs; by expressing relations as tuples enriched with attributes. Also, other Data Modeling paradigms more specifically explored in the Architecture, Engineering, and Construction (AEC) realm, such as (Extended) Entity Relationship Models (EER), Object Role Models (ORM) are already structured as networks. This makes their direct transfer to GDBs possible, while maintaining functionalities such as “attribute sets” in querying the resulting structures through clustering.

Graph Databases (GDB) are database architectures structured to permit network analysis methods on structured data. These databases are built using graph structures comprised of Nodes, Edges, and Properties (Labels or Attributes). These structures can be explored with semantic queries while storing data in an inter-related manner.

In the Process Modeling domain, common methods of rigorous communication, such as BPMN or UML—and its more engineering focused subset SysML, derive their validation and semantic execution capabilities thanks to their directed network structure. Again, making it possible to transfer native process model information to GDBs.

While these structures can be observed in information models related to building and design practice, in this paper we want to extend the Network Model towards the cognitive processes that are part of design and engineering, to this end World Graph (WG) theory, a metaphysical framework. (Dipert, 1997) WG provides a scaffolding to lay out the interactions between cognitive and motivational states that are part of the decision making.

Within this context, attention is given to Small World Networks, which are graphs that can be used to represent frequently encountered problem spaces. A caveat is, that AEC information spaces can present themselves very scattered overall, while tightly clustered within different expertise domains, e.g., paneling dependent on very intricate hardware of many low tolerance components; or material differences in common building methods, such as RC detailing. This is why we believe SWN models can be good candidates for structuring cross domain relationships in a process and object oriented AEC workflow bridging the gap between human cognition and Building Information Models, using rigorous methods, tried and tested in the realm of network science and graph theory.

To this end we will demonstrate Graph mappings of design parameters (affordances, objectives, etc.), material properties (ductility, weight, etc.), logistics (order, transportation, etc.), and fabrication methods (shaping, fitting, etc.) tracing a contiguous network between expertise domains, as a proof of concept for developing a common modeling environment between human understanding, communication and storage tools in AEC problem spaces.

Keywords: Semantic web, IFC, graph databases, design cognition, process model

INTRODUCTION

Building information modeling (BIM) processes are collections of various tools, methods, legal and information schemata aimed at creating digital environments for creation, management and storage of representations of diverse elements such as, physical spaces, material properties and scheduling arrangements regarding the built world.

The results of this process is generally a BIM repository that contains data regarding assets in a structured manner. Thanks to the ready availability of information from different expert domains and many

aspects of building operations; users can extract, exchange, or derive information without separate Requests For Information (RFI) that are common causes for communication errors and delays in Architecture, Engineering and Construction (AEC) workflows.

Currently most Building information models (BIMs) are stored in proprietary file formats and there is a push from the software industry to offer BIM services such as hosting and access control on remote servers and within proprietary frameworks (BIM360, Procore, Bluebeam etc.).

Within this context most products have their own internal structure to organize project related data, building object classifications and even different geometry modeling kernels. This makes interoperability and standardization a challenge onto itself.

BuildingSMART is the international body that has developed Industry Foundation Classes (IFC), the most widely adopted and open interoperability format. IFC is also a registered standard by International Organization for Standardization under ISO 16739-1:2018.

A further observation to be made is that while topological connectivity information is generally present while drafting in a BIM Suite, much like geometric constraint satisfaction and, the analytic computer graphics solutions that are at the core of user interfaces, most of this information is not transferred outside of their initial realms.

1. IFC, SEMANTIC WEB AND ATOMIC GRAPHS

IFC provides an Entity-Relationship (ER) model that supports validation and is based on EXPRESS data modeling language, the ISO standard for Product Exchange models (STEP ISO:10303-11:2004). The structure of an EXPRESS, thus IFC, model is of a networked nature. EXPRESS model schema is a plain text file that presents itself as a series of separate lines using Wirth syntax notation (WSN) (Wirth 1977). Limited to a subset of Unicode Basic Latin Block, it incorporates three commands from the C0 control stack, supplemented with a newline special command “\n”. This straightforward and barebones approach lets EXPRESS be readable by humans and by computers for validation, and host various aspects of “the diverse material addressed by ISO 10303” (STEP ISO:10303-21). Within this frame, EXPRESS language focuses on definition of entities with properties and constraints. EXPRESS is context neutral, can host multiple data type definitions with their own algorithmic rules, and supports specification of models for specific views.

While EXPRESS is the primary schema adopted for IFC, different research efforts are underway for representing the relation-network information present in IFC through other schemata. Web Ontology Language (OWL) and Resource Description Framework (RDFs) or Extensible Markup Language (XML) and XML Schema (XSD), which are data modeling approaches for Semantic Web and the Internet developed and standardized by World Wide Web Consortium (W3C) are considered equal alternatives to EXPRESS-IFC by BuildingSMART under the names of ifcOWL and aecXML.

XML-XSD and OWL-RDF are tools that have been developed for data exchanges outside the realm of AEC. Both establish machine readability for content as a prime goal. While XML states the intent of being human

readable, the level of cognitive permeability changes from context and implementation; likewise, OWL-RDF with different syntaxes and serialization formats offer differing degrees of human readability. By specification, Semantic Web foresees machine readability of the World Wide Web through enrichment with structuring. While large scale implementation over the internet of Semantic Web is still a future aspiration, specific domain applications are already implemented and in use.

In the following section, RDFs with their “subject-predicate-object” type structure handle triples as atomic entities for codifying semantic data. This atomic component presents the smallest Directed Acyclic Graph (DAG), that is a directed relation through predicate between the subject and object. This entails that by forming relationships in this manner while the basic building block remains relational, we can construct Graph Structures for data representation.

The standard query language for RDFs is “SPARQL Protocol and RDF Query Language” that provides NoSQL methods and graph traversal syntax. Furthermore, SPARQL has also implementations that support both relational (Apache Marmotta, etc.) and graph databases. (Amazon Neptune, Oracle Spatial & Graph, etc.)

Triplestores can also be expanded to include more information through layering to satisfy descriptions for more complex information. Such as Molly->IS->Cat; Molly->WATCHES->(Squirrels-IN->The Backyard). The predicate can take more than one target: Molly->IS->(Cat, Tabby). The triples can also be named thus becoming “quadstores” or named graphs. Molly->IS->Cat can be identified as natureOfMolly and can be stored as a quad consisting of <subject>, <predicate>, <object>, <graphName>. More specifically, these names are Uniform Resource Identifiers (URIs) or Uniform Resource Names (URNs). Using named graphs and layering we can extend the type of graphs we define to directed multigraphs (allowing loops) and define hyperedges (connecting more than one vertex).

Each relation defined in an IFC can thus be hosted in this type of relationship and ifcOWL (Pauwels, & Terkaj 2016) that uses OWL instead of EXPRESS schema. This has been implemented in various tools and can be used to infer information to use in concert with Linked Data (LD) or, in particular, Linked Open Data (LOD) that is adopted by several governments across the globe (Holm et al., 2012). OWL can maintain the well detailed and conventional IFC standards for representing construction data, while expanding the capabilities of data distribution, extensibility, reasoning and knowledge inference. ifcOWL also permits validators that are key for BIM standards as can IFC-EXPRESS and aecXML. Also, some Business Process Models that will be discussed further have similar validation capabilities

due to their linked nature. One notable advantage of OWL over EXPRESS is a wider semantic lexicon than basic EXPRESS schema without use of specific Model View Definitions (MVDs).

2. GRAPH DATABASES

Relinquishing the atomic structure of Triplestores, we have the option of branching out into the realm of Graph Databases. Graphs, in the broadest sense, are structures that are comprised of a set of discrete elements (vertices) and a set of tuples that establish relationships (edges) between them $G = (V, E)$. GDBs, which use graph structures to store and organize data, are again NoSQL databases that present a networked structure. Different than the RDF-OWL approach, GDBs organize the data in a graph of nodes, edges and properties, instead of relying on atomic sentences. As an approach to data modeling, these are akin to the natural view of ER models; as every data element is an explicit entity with types and the relationships between these, are expressed as entities in their own right (Chen 1976).

The elements themselves can have pointers associated instead of having to cite URIs. In a more abstract manner, every element contains pointers to their adjacent element, doing away with the need for index lookups typical of relational databases. This latter property, opens many interesting possibilities as it permits localized solutions on building element interactions on models in contrast to serial ones. In previous research (Bermek, Gentry, and Shelden 2019), we have proposed graph database layers to include proximity information for encoding spatial and material information parsed from IFC files. This was intended for creating robust, cross domain, and rule-based reasoners for Cross Laminated Timber structures.

The property related focus of `IfcArchitecturalDomain` does not necessarily represent structures and connectivity in the IFC file. Rather, if there is a structural model developed within the design process, then IFC provides methods for exporting structural models between structural analysis softwares. While physical element connectivity ontologies are present and key in the `IfcStructuralAnalysisDomain` (since IFC2x), in the architectural domain `IfcRelationship` and its subtypes define relationships between elements of the model. There is no common integration between an object represented in the structural model space with its spatial and assembly constraints and its role as a structural element. That is, the structural domain and the architectural domain serve purposes of interoperability within their respective design realms. This certainly is useful in certain construction types like RC, or steel structures that create a schematic

canvas onto which architectural and system elements are loaded; but does not respond to the nature of construction methods in which the building element has a hybrid role (i.e. masonry, composites, mass engineered timber).

`IfcRelationship` is an abstract generalization of relationships that can have objectified attributes. All the properties are handled at the relationship level and behavior is not directly prescribed while asserting relation. Relying on the Entity Relationship (ER) Model, the relations can be one-to-one and one-to-many but always with a relating and related party.

Among the subtypes of `IfcRelationship`, `IfcRelConnectsWithRealizingElements` can be used to define exteriority relationships, that is to populate an existing model by interstitial elements that establish and reify a connection between disparate elements. This is defined as a ternary relationship. This is a very welcome addition to the IFC4x schema and supersedes the hierarchical nature of relationships defined in previous versions (`IfcRelAggregates`, `IfcRelDecomposes`).

When established, these relationships of exteriority are the key to modeling entities in an adaptive way. As we have underlined when talking about triples, the basic 3 component triple is nothing but a two vertex complete graph ($K_2: 1$) and we can deploy our IFC schema fully using these atomic graphs. The advantage of using a GDB representation for our BIM is thus twofold. For one we can safely accommodate the property-based information that is typical of and IFC file in whichever detail we want. Secondly, we can, through the ternary relation established, populate our geometric model while using other `IfcRelationship` subtypes that define different types of relationships used to model the design space with better fidelity, reliably, and without needing to expand our basic schema (figure 1).

These tools have been covered for outlining the possibility of representing any BIM within a Holistic model, where spatial relationships affecting design, fabrication, or other construction choices can be hosted in its entirety and can be further expanded with secondary property derivation. Property derivation and reasoning are elements on which we will rely heavily (Solihin and Eastman 2015).

Considering:

- How a Graph is a set of vertices associated by a set of tuples that represent connectivity between the vertices, defining relationships (edges),
- Vertices and edges can support labels or properties,
- That the entities, abstract or reified, can be part of different sets within a space (our database),
- Sets of elements themselves can have many associated connectivity sets (multiplex networks),

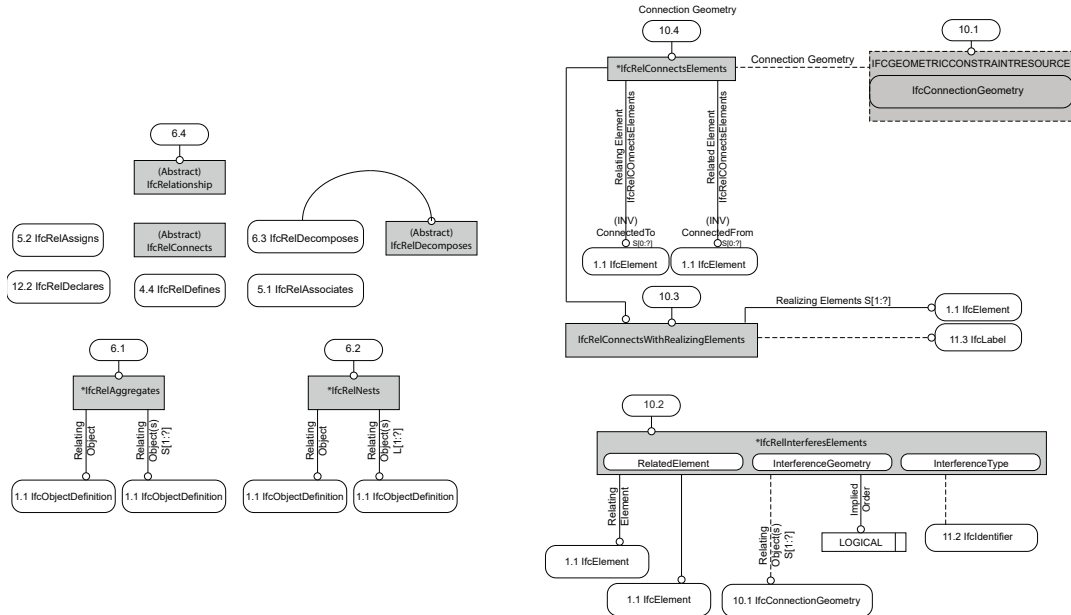


Figure 1: IfcRelationship and subtypes (buildingSMART IFC EXPRESS-G Schema). (Redrawn by the author, 2020)

- We can represent our system and subsystems as a structure of differing complexity: *Assemblages*.

3. EXTERIORITY, ASSEMBLAGES AND GRAPHS

Assemblage Theory is a framework first detailed by French philosopher Gilles Deleuze and philosopher and psychoanalyst Félix Guattari in their *A Thousand Plateaus* (2013). The theory provides a scale independent approach that is used for analyzing social phenomena and complexity, putting the changing nature of things in the foreground. This approach derives its essential features from dynamical systems theory, which is the mathematical approach to model chaotic, non-linear, or complex systems. Assemblages assume that parts of a body don't have fixed relationships or interior roles that they are executing within the system; these are rather independent entities that "happen" to be organized in a given manner at a moment in time; their relations are amenable to change. Entities can assume multiple functions and can be replaced or displaced, moving away from an organismic parable of interiority.

These structures—or dispositions—can accommodate self-organization, and conditions that are not intentionally acting on the elements. A common anecdotal example is a ready concrete mix changing properties due to the transit mixer being stuck in traffic or the driver stopping for lunch: A completely unrelated event, changing characteristics of a merely tangent system in a separate domain.

In their discourse Guattari and Deleuze refer to *constellations*. These are a collection of accidentally interrelated properties (cfr. abstract entities) and elements of differing nature. They individuate a plane in which the axes define the level of territorialization and coding. The most coded sectors indicate where matter is most organized around a body. Likewise, the most territorialization is when demarcations become most apparent. Through this particular configuration or form the assemblage composes and establishes a territory.

The apparent hierarchy and stratification of systems is a byproduct of territorialization thus, the vantage point of the observer defines the actual relationship between bodies that can be experienced differently by different actors. Once established, material forms and expressive forms do not remain static, territorialization is a continuous superposition of "build-up, break-down" processes. As an example: while the "construction crew" at the early stages of a building is mostly composed of workers with experience in earthworks, reinforced concrete and formwork, in the later stages of the same project, the composition of the "construction crew" is predominantly carpenters and HVAC technicians. The very workers part of the "crew" at the beginning are possibly part of another project by the moment of delivery. Thus, the transient involvement of any single agent demonstrates the complex manner in which these *assemblages* come into being.

In recent years, philosopher Manuel DeLanda started detailing the concept of assemblages in his 2006 work *A New Philosophy of Society*. His core tenet in expanding the two axes plane into a higher dimension by adding the axis of Genetics-Language (nature-nurture) gives way to dynamic re-coding of the assemblages. While mainly talking about complexity of society in formulating the perceived dynamics and configuration of assemblages, his work has had a profound impact on the study of complexity and geography. DeLanda emphasizes that reality and materiality are independent of their degree of complexity. Concluding that being fluid and mutable in nature and not pinned down to specific components, reading social or material structures as assemblages, does not make these less incisive world altering processes.

As formalized, assemblages at a given moment in time can be represented as a complex, topological network with varying levels of connectivity. These networks can accommodate representations of processes involved in AEC workflows with high levels of detail as they are theoretically multi-scale structures that represent different aspects within the same model. While the nature of the network graph would permit a possibly infinite amount of information to be represented due to its ontology, in practice the capabilities would be limited by the breadth of our *semantic lexicon*, storage, and computation capacity. Notwithstanding these practical considerations the unified representations of "the totality of the building process" would generate models and simulations of currently unachieved levels of detail and power. The vision of a possible model has already inspired different levels of characterization of BIM models. Current state of the art is referencing 7D BIMs as models capable of supporting building asset management life cycle.

Scale-free networks are networks characterized by edge numbers that have a distribution according to power law. These are different than totally random maps as they foresee a diversification between node degrees. That is, having a given number of nodes that have a notably higher degree (number of associated edges) than others. With the degree distribution of the nodes following a Pareto distribution—or the power law—with long trailing ends. Social Networks and, more importantly for our case, Collaboration Models are prime examples of this type of network. The generative processes behind these kinds of networks exhibit preferential attachment stemming from a fitness model. This is to say, stronger elements in a system have more effect in further configuration of their network. Real world examples of these networks represent the *Matthew Effect*, or the "rich get richer" or "success breeds success" dynamic as can be seen in the

distribution of citations of scientific publications, or web page and media click counts. (van de Rijt, Kang, Restivo, and Patil 2014) This tendency becomes relevant to our case in questions regarding continuity of technological systems, and tracing of loads through a structure.

Finally, a strictly related network topology is the small-world network that is defined by degrees of separation. These scale-free networks, as will be mentioned in our main focus, are very-small (or ultra-small) world networks. In scale-free networks, distances between nodes can be $\log(\log(n))$ whereas in random graphs (or Erdos-Renyi graphs) distances converge towards $\log(n)$. (Strogatz, Watts 1998) (Cohen, Havlin 2003)

The small World Hypothesis formulated in 1929 by Hungarian writer Frigyes Karinthy, better known as "six degrees of separation," has been the subject of research throughout the 20th century. Watts and Strogatz 1998 state that, with the addition of only a limited number of wide spanning edges, a regular graph can become a "small world network," where the growth of average number of edges between two given nodes is much smaller than the growth of the size of the network. This is to say that in small-worldness most nodes are not neighbors of each other, but require a small number of steps to reach each other. This property is suitable for optimized human brain networks, reducing energy and dendritic process lengths.

As presented, a networked representation of components of complex systems can yield a higher fidelity model than arbitrary subdivisions and reductionist tabulations typical of a top down, one-size-fits-all standardizations. As a fragmented and static encoding of information about a system that is undergoing shaping, it is not able to convey a contiguous idea of wholeness. This is especially inconvenient regarding the engagement of actors with the process of design.

4. DESIGN DOMAINS AND LOSS OF CONTINUITY

Thought processes and information requirements for design, procurement, fabrication, and assembly can be extremely complex to encode or comprehend with a single language or through a single lens. Different actors are going to approach the same object, treat the same process differently, have conflicting ideas, and supersede decisions made in different stages.

Every item in a complex system can be represented as a stratification subsystem with varying degrees of interaction among themselves. We have seen these in the emergence of assemblages, or as substructures in Dipert's WG. In dealing with the scales involved in design, manufacturing, and AEC workflows, these subsystems can be exemplified by tangible objects or shared conventions in an intuitive manner. Where interactions are dictated not only by spatial

proximity, but also agent and organization based rules: for example when the painter who is going to apply the actual pigment in a room has less effect on the color of the walls than an e-mail exchange between the contractor and the interior designer. The only reason the project coordinator will be informed will be due to coercive form filling requirements borrowed from corporate practices where liability rules supreme and every actor is as alienated from design exploration, as the painter is from their labor. For lack of an adaptive design-planning-building medium.

In the AEC field there are communication systems and calcified roles that are pervasive. These govern the nature of the information transmission and decision making within process and agent interactions involved in delivery of product. It would be beyond the capability of any single innovation to change the way we build. Even suggesting a disruption of traditional hierarchies would probably generate more interest than genuine change. Yet as the nature of our buildings become increasingly complex, the life-cycles for buildings and functions therein imagined are ever more interconnected. This complexity generates novel resources, affordances, risks, and conflicts. Shaping our substrate for communication and collaboration through the lens of a position that will not acknowledge this new reality will, at best, yield us another barren and obsolete "iron cage" of a Weberian dystopia.

5. MANY ACTORS, ONE PRODUCT

Looking back at the brief narrative to appreciate the discontinuities inherent in a construction workflow, while putting contingencies in the forefront:

The owner decides on their needs, architect decides on the layout, this places a certain function in a certain position in relation with the environment prescribing the exposure of the volume in relation to the sun, in a different moment in time, the architect decides on the openings of this space based on requirements dictated by concerns of accessibility, facade systems, and architectural style. So, the solution for the space in which a given function will be hosted is bound by a series of conditions based on decisions made. Then an external agent, an acquaintance of the owner, recommends an interior designer. Through dynamics that go beyond our scope the owner is convinced.

The interior designer comes into play and must decide on the finish that is going to be applied. They have to rely on societal norms or evidence based research or their decisions, and these prescribe what communication tools they will use to convince the owner on the validity of their decisions (samples, swatches, rendering, etc.) a decision is reached, the contractor subcontracts the work to a team of painters

and they verify availability of the finishes and so forth.

Each solution is contingent on a series of decisions that are formalized in varying degrees, resolutions, and contexts. All the while, each actor is bent on refining their involvement and successful delivery from their own perspective. These relationships have been formalized in various diagrams and workflow languages that facilitate information flow and role distribution. These tools can be ad hoc, informal, or studied and carefully programmed using tools from Process Modeling domain, such as UML or BPMN. Their validation and semantic execution capabilities are due to their directed network structure. These latter are rigorous methods of planning that support validation and unequivocal communication. Yet at the end of the process, they are lost, once a specialist retires, and their experience and knowledge in having encountered different conflicts is pulled out of the common toolbox (Wong et al. 2000). Opening our cognitive or computing models to informal practices that can be formalized under one schema can yield better capabilities for parsing and searching that will permit benefiting from better affordances and can be used to automate process optimization efforts (Kitchin 1994).

It is important to note that a trend among AEC software providers on the other hand has been that of moving BIM applications onto the cloud for purposes of data mining, or data sniffing. These metrics, and the knowledge that they are collecting and using, are sold back to the project owner as a service, or third parties as industrial insight. All this naturally happens behind the private software suite interface, within the company, and with methods not necessarily published.

CONCLUSION

As stated, finding a common language between actors or even different operations by a given actor is not easy to develop. This is due to the differing nature, temporal and spatial distribution of agents, tools, and environments in which fabrication, logistics, and assembly operations take place. The first research gap that is identified in a systematic review of 259 papers regarding multi agent BIM projects for infrastructure is in line with our proposal of developing a rich connected information substrate:

"[...] a growing use of ontologies, linked data techniques, and big data style approaches are reducing the need for stringent, structured data formats, weaving together data using graph based approaches processed via reasoning, rule engines and machine learning" (Bradley et al. 2016).

Their indication of a downside for this approach is a result of the lack of information and computer science knowledge within the AEC community (NB:

according to them AECOO: Architecture, Engineering, Construction, Owner, and Operator is the industry subset directly dependent on BIM). Our understanding is that, while this condition holds true, it is partially due to the disconnect with the analytical methods hidden behind the software's user interface. This lack can be exemplified in Bresenham's algorithm (or Wu's algorithm), solving a raster result for an analytical line in the modeling space. The result is the designer or other specialist's only window into the operations happening "under-the-hood".

The designer or the technician involved in these processes resolves only one given aspect of the operation at a given time. The way we can make sense of this unfathomable amount of information is by introducing vagueness and abstraction. In the same way the vantage point around an assemblage can change our perspective by letting parameters that are not critical to the problem, ebb and flow into focus, we can make sense of temporal roles and progress in the definition of a solution.

Research into implementing mechanisms of human cognition in a BIM setting is emerging. Work on visualization of vagueness in Multi-LOD (Level of Development) BIM (Abualdenien and Borrmann 2019) opens another way of virtualizing the chunking of the information for the benefit of clarity of scope in design problem solving. Mimicking the design communication methods of a traditional setting is one example of how one can start chiseling at the monolithic and prescriptive nature of today's building design.

Within this context, affordances are entities that satisfy actor or process needs and hidden affordances

are parameters that lie in proximity to the network, but in a different domain or cluster. Having the semantics of these entities searchable would yield unprecedented opportunities in resource sharing while being able to limit case searches to spatial proximities as previously mentioned. Graph structures are also well suited to defining optimized scheduling or to serializing design automation, reducing the need for specialist intervention in repetitive tasks.

The explicit representation of all entities and parameters in a networked manner will most definitely resolve the problems of compartmentalization, data loss, and repeat derivations within today's AEC workflows. Once established proofs of concept for project-wide graph processing are established, the pitfalls of expanding the knowledge base wider than previously attempted need to be identified.

Semantic Web applications for derived cross domain layers in BIMs are a promising prospect. There are still no standardized GDB solutions for BIM standards. Although graph applications and Free and Open Source Software (FOSS) BIM topics are entering the literature, there are no implementations or experiments that reach a substantial user base (Ismail et al. 2018; Logothetis et al. 2018). ifcOWL is a promising concept for rigorous and standardized semantic interoperability applications for data derivation, and there are already applications for cross domain information retrieval (Petrova et al. 2019). Today's technology can also support localized GDBs that would be able to open the door for cross domain automation and optimization, at the reach of the participants of the design, construction, and living processes.

REFERENCES

- Abualdenien, Jimmy, and André Borrmann. 2019. "A multi-LOD Model for Visualizing Building Information Models' Vagueness." Proceedings of the 2019 ASCE International Conference on Computing in Civil Engineering, Atlanta, U.S.A.
- Bradley, Alex, Haijiang Li, Robert Lark, and Simon Dunn. 2016. "BIM for Infrastructure: An Overall Review and Constructor Perspective." *Automation in Construction* 71: 139-152.
- Bermek, M. S., D. Shelden, and T. R. Gentry. 2019 "A Holistic Approach to Feature-based Structural Mapping in Cross Laminated Timber Buildings." EcaadeSigradi, Conference Proceedings.
- Cohen, R., and S. Havlin. 2003. "Scale-free Networks are Ultrasmall." *Physical Review Letters* 90, 058701.
- DeLanda, Manuel. 2019. *A New Philosophy of Society: Assemblage Theory and Social Complexity*. Bloomsbury Publishing.
- DeLanda, Manuel. 2016. *Assemblage Theory*. Edinburgh University Press.
- Deleuze, Gilles, and Félix Guattari. 2013. *A Thousand Plateaus: Capitalism and Schizophrenia*. Bloomsbury Publishing.
- Dipert, R. R. 1997. "The Mathematical Structure of the World: The World as Graph." *The Journal of Philosophy* 94, no. 7: 329-358.
- Hendler, J., J. Holm, C. Musialek, and G. Thomas. 2012. "US Government Linked Open Data: Semantic. data. gov." *IEEE Intelligent Systems* 3: 25-31.
- International Organization for Standardization [ISO]. 2018. Industry Foundation Classes (IFC) for data sharing in the construction and facility management industries (16739:2018).

Graphs, Sets & Covers; Seeing What Has Been There

- Ismail, A., B. Strug, and G. Ślusarczyk. 2018. "Building Knowledge Extraction from BIM/IFC Data for Analysis in Graph Databases." In *International Conference on Artificial Intelligence and Soft Computing*: 652-664.
- Kitchin, R. M. 1994. "Cognitive Maps: What are They and Why Study Them?" *Journal of Environmental Psychology* 14, no. 1: 1-19.
- Logothetis, S., E. Valari, E. Karachaliou, and E. Stylianidis. 2017. "Spatial DMBS Architecture for Free and Open Source BIM." *International Archives of the Photogrammetry, Remote Sensing & Spatial Information Sciences* 42..
- Pauwels, P., and W. Terkaj. 2016. "EXPRESS to OWL for Construction Industry: Towards a Recommendable and Usable ifcOWL Ontology." *Automation in Construction* 63: 100-133.
- Petrova, E., P. Pauwels, K. Svidt, and R. L. Jensen. 2019. "In Search of Sustainable Design Patterns: Combining Data Mining and Semantic Data Modelling on Disparate Building Data." In *Advances in Informatics and Computing in Civil and Construction Engineering*: 19-26.
- Solihin, W., and C. M. Eastman. 2016. "A Knowledge Representation Approach in BIM Rule Requirement Analysis Using the Conceptual Graph." *ITcon* 21: 370-401.
- Van de Rijt, A., S. M. Kang, M. Restivo, and A. Patil. 2014. "Field Experiments of Success-breeds-success Dynamics." *Proceedings of the National Academy of Sciences* 111, no. 19: 6934-6939.
- Watts, D. J., and S. H. Strogatz. 1998. "Collective Dynamics of 'Small-world' Networks." *Nature* 393, no. 6684: 440-442.
- Wong, W. L. P., and D. F. Radcliffe. 2000. "The Tacit Nature of Design Knowledge." *Technology Analysis & Strategic Management* 12, no. 4: 493-512.

OVERSEAS EXHIBITIONARY EVENTS AS THE DICTATOR OF CONTEMPORARY CHINESE ARCHITECTURE: “TU MU: Young Architecture of China” in a World Media System

Dijia Chen
University of Virginia

Abstract: Focusing on the first European exhibition staging independent Chinese architects “TU MU: Young Architecture of China”, I investigate the process in which overseas architectural exhibitions instigated the recognition of the neglected, marginalized, and suppressed independent Chinese architects, both at home and abroad. Curated by the Europeans, the exhibition appropriated the peripheral Chinese practices into the discourse of world contemporary architecture, established the architects’ advantaged position in the design market and academic institutions, and ultimately empowered the creative class, instead of the state-owned institutes, to represent China on the world platform. In this research, architectural production is approached as a mediated culture phenomenon rather than the construction of physical buildings in a local setting. I first analyze the distinctive media systems in China and Germany as the prerequisites of the exhibition; I then identify the empowered and disempowered institutions, entities and individuals in the constructed narrative. Positing Chinese participants as voiceless object, I conclude the paper by problematizing the consolidated discourse in terms of subjectivity, identity and authorship, and evaluate its broader impact on the younger generations in China’s architectural circle today.

Keywords: Contemporary Chinese architecture, exhibitionary event, narrative, transnational cultural communication

1. REVISITING THE NEGLECTED EXHIBITIONARY EVENTS

In the late 1990s, independent Chinese architects emerged as a resistance to the dogmatic functionalist buildings mass-produced by state-owned, mainstream design institutes. Due to its marginalized position, the group was unknown to the world until a series of exhibitions held in Europe. Starting with “TU MU: Young Architecture of China,” an exhibition held at Aedes Architectural Forum, Berlin in 2001, the overseas exhibitions worked as manifestos to push forward the self-adjustment, maturation, and recognition of a previously “out-of-the-system” architectural practice in China. The independent Chinese architects, an underrepresented and even suppressed group in the dominating planned economy (despite the marketization of real estate since the 1990s), rapidly obtained popularity and recognition in the domestic market, governmental projects, academic institutions, etc. While the design institutes took up the majority of the construction works at the time, this small group of independent architects became the accepted representatives of “contemporary Chinese architects”, both at home and abroad. The transnational exhibitionary events in the transitional period of the late 1990s to early 2000s, therefore, play a decisive role in the making of contemporary Chinese architecture as a cultural phenomenon in the world media system.

The so-called “independent Chinese architects” is a vaguely defined group that generally refers to the

individual designers that are not attached to any state-owned design institutes. Since the 1950s, the design institutes have been in charge of all the design and construction works in China. Like most of the other production institutes under China’s planned economy, the design institutes produce architectural works that are efficient, functionalist and anonymous. All architects are cogs in the giant system, and no individual designer is credited for the work.

The context in which architectural experimentation took place was characterized by the transformation to a socialist market economy in Deng Xiaoping’s time. In the 1990s, the re-opening of the quasi-capitalist market and the gradual establishment of a licensing system for individual architects have enabled the preliminary development of the first privatized studios. The “out-of-the-system” architects, in this context, started to explore alternative practices as scattered individuals. This group of architects, commonly referred to as “experimental architects” (Wang and Shi 1998; Rao 2000) or “avant-garde architects” (Li 2004; Vlassenrood 2006) in China, are generally underlined by their overseas architectural education experiences, affiliations to universities in major Chinese cities, small-to-medium-scale, privately or university-commissioned projects, and a critical attitude towards the rapid large-scale urbanization process promoted by the design institutes. Due to the ambiguity of both terminologies that defines them, I use the term

Overseas Exhibitionary Events as the Dictator of Contemporary Chinese Architecture

"independent Chinese architects" to articulate the group as insubordinate rebellions opposed to the mainstream, collectivist system in China.

The independent practices were peripheral and marginal back in the 1990s. Mainstream academic journals focused on reporting the large-scale, state-planned projects and posting brief introductions to western architects, while the writings and design works of the independent architects were never published. The debut of this group, the 1999 exhibition "Experimental Architecture by Young Chinese Architects (Zhongguo Qingnian Jianzhushi Shiyan Zuopin Zhan)" curated by Wang Mingxian during the UIA Conference was half-closed. Nevertheless, the German architect and curator Eduard Koegel was fortunate to have observed the staged architects before the exhibition opened, which marked the first western encounter with the independent Chinese architects and inaugurated a series of exhibitions on the same group of architects in Europe in the following years.

"TU MU: Young Architecture of China" was an exhibition project curated by two German architects: Eduard Koegel and Ulf Meyer at The Aedes East Forum. The exhibition features the works of six young private architects and artists from China (Aedes 2001). While it was the first overseas exhibition to break the western stereotype of China as "the biggest construction site in Asia", and to inaugurate new debates on the identification and categorization of emerging independent Chinese practices in world's contemporary architectural culture, "TU MU" is astonishingly understudied in the Chinese world. Only two brief newspaper reports in 2001 and a retrospective memo of the German curator in an academic periodical in 2016 are found. In Germany, on the other hand, the exhibition was reported with multiple perspectives in the major newspapers in 2001, a *Bauwelt* monograph accompanying the exhibition was published, and the director of the gallery still talks excessively about the exhibition in an interview in 2018 (Commerell 2018).

In this research, I investigate the exhibition "TU MU" as a transnational cultural event facilitated by diverse media systems, asymmetrical power structure, and uneven capitalist development, and radically re-examine the formation of contemporary Chinese architecture as an intellectual construct, a hybrid discourse, and a commodified and politicized image. First, I analyze the social, political and cultural characteristics of the media systems in China and Germany to reveal the determining prerequisites that instigated the exhibitions. I further center my study on paper-based media, the dominant medium of dissemination, both in mass communication and academic circles before the Internet. By identifying the empowered institutions,

entities and authors through a "close-reading" of the press release introductions, newspaper critiques, news reports, and monograph articles, I posit the Chinese participants as voiceless objects in the constructed narrative. Finally, based on Said's (1979) notion of Orientalism and Bourdieu's (1993) field of cultural production, I conclude the paper by problematizing the consolidated discourse in terms of subjectivity, identity and authorship, and evaluate its broader impact on the younger generations in China's architectural circle today.

2. CHINESE ARCHITECTS GO TO EUROPE: TRANSNATIONAL EXHIBITIONARY EVENTS IN A WORLD MEDIA SYSTEM

The late 1990s and early 2000s saw the formation of a global media system, when newspapers still dominated as one of the major mediums for mass communication before the popularization of the Internet (McChesney 2001, 2). With its major circulation within regional boundaries, the newspaper underlined an era when local distribution overwhelmed global influence. In this context, the media systems of different countries were more isolated than connected. Information flowed across national borders indirectly, yet dominant cultures still exerted ideological influences on the disadvantaged countries. In the case of "TU MU", the great difference between Chinese and German media systems facilitated the exhibitions of independent Chinese architectural works in central Europe.

The so-called "journalist freedom" in the west has long been absent in China. On the one hand, the Chinese media system is haunted by the Soviet model that works more as state ideology apparatus which rejects the multiplicity of voices. (Schramm 1964; McQuail 1994, 131). The journalists' official role-definition is ostensibly to be party propagandists (Zhao 2012, 162). The state has been in charge of ideological control since feudal China. On the other hand, since the first modern newspapers in China were set up by foreign colonizers in port cities during the early 20th century, privatized media threatened to be "capitalist restorations" in the socialist system. While a gradually capitalized media industry has been developed under great caution since the re-opening policy of 1992, over 95% of newspapers were still governed by national and local authorities. The very few privatized ones focused on lifestyle, business, sports, and information technology, which are generally a-political. News reports have always been under the tight control of state-owned press. The high "party-press parallelism" (Hallin and Macini 2004) characterizes the broader social background that prevented the circulation of Independent Chinese architects in domestic media reports.

Under mass urbanization and the burgeoning quasi-capitalist market, the identity of the independent

architects is inscribed with multiple significations. First of all, by criticizing the mass-produced, quick-finished building projects that ignore the urban-rural division, cultural traditions, and environmental issues, they stand against the image of a new, modern China constructed by the government. While the authority endeavors to accomplish large-scale projects to represent a modernized and powerful China, the independent architects appear politically dissonant by returning to small-to-medium-sized projects, traditional aesthetics and indigenous building materials. Furthermore, as practitioners that do not comply with the socialist organization of the design institutes, the architects' position is somewhat questionable in the society. Although they represent an emerging force on the blossoming marketplace, very few of them were registered architects, which raised questions before the exhibition on whether they should represent China- (Koegel 2019). Moreover, as public intellectuals based in universities under the avant-garde influence of the ideological emancipation of the 1980s, the group is closely related to the rebellious contemporary artists. Finally, since most of them received overseas education, the group modeled their professions on their western counterparts, while experimenting on the modern interpretation of traditional aesthetics. Their positions are incompatible with the mainstream ideology.

It is no coincidence that the positions suppressed at home found their way out in a different cultural context. The German media system, as is analyzed by Hallin and Mancini (2004) under the category of "democratic corporatist model" in North and Central Europe, contrasts with the Chinese system in its high professionalization, low state-interference, early maturation of press freedom and strong criticality. Due to its traditions in limiting state power, early and strong development of liberal institutions and the early formation of civil society (Hallin and Mancini 2004, 197), Germany is one of the Central European countries which has developed a strong commercial media market with "a journalistic culture in which the role of opinionated editor and commentator" has an important place (Hallin and Mancini 2004, 158). On the one hand, the Protestant ethics of self-organized churches and the capitalist spirit instigated the rebellious traditions in journalism; on the other hand, the journalistic autonomy and criticality in the media system became a major guarantee for pluralism after WWII. The competitive commercial media markets and the multiplicity of political voices push forward the professionalization and criticality of journalists, who are explicitly oriented towards market interests compared to that of China, where major newspapers depend on institutional subscriptions.

Therefore, the German media institutions and individuals welcomed the Independent Chinese architects, either as a rebellious gesture to break stereotypical views and evoke debates inside Europe or as a supportive act to empower the Chinese participants by emphasizing their critical stance. The Chinese participants, on the other hand, yearn for the opportunity to be involved in world-class cultural events. The event thus stands as a transcultural communication instigated by the unparalleled development and the political, social and market forces in the world media system.

3. IDENTIFYING "TU MU" IN A EURO-CENTRIC CONTEXT: AUTHORSHIP, SUBJECTIVITY AND THE IMAGE

To understand an architecture exhibition as an "event" is to recognize its complexity in constructing historical moments and hybridizing asymmetrical power relations between different institutions, entities and individuals. As is defined by Dayan and Katz (1994), media events include "epic contests of politics and sports, charismatic missions, and the rites of passage of the great", as "high holidays of mass communication" (1), which gather mass audience to suspend their everyday routines to join a pseudo-event. Architectural exhibitions, in comparison, have no such appeal to the general audience, but they construct an event that is held in a designated time period, synthesize various media approaches, gather professionals, critics and architecture lovers, appeal to media coverage, evoke disciplinary debates and critiques, and, if successfully organized and reported, become hallmarks in promoting architectural discourse. Based on the definition given by Dayan and Katz, I see architectural exhibitions as media-saturated occasions in an imagined community that constructs the assemblage of meaning. As "events," the influence and effectiveness of the exhibition are determined by the dissemination, circulation and interpretation of its media content, either in the forms of mass media reports or professional critiques.

In the case of "TU MU", an exhibition held in 2001, major reports and critiques were disseminated through paper-based media, including the press release, catalogs, newspaper articles and critiques in academic periodicals. These texts sufficiently reflect the power structure that looms over the exhibition. In China, the major institutions and entities involved included the Chinese government, the state-owned newspapers, newly established architecture schools in universities, emerging private galleries in big cities and academic periodicals in architecture; in Germany, the gallery, the curator, the journalists and the editors of the academic periodicals all have a voice in shaping the event.

Overseas Exhibitionary Events as the Dictator of Contemporary Chinese Architecture

As is discussed above, the general socio-political environment back in China was hostile to independent architects. The Chinese government and the mainstream architects were actively promoting the modernized urban image of China. According to an interview with the curator and his retrospective commentary in 2016, "TU MU" in this context was suppressed by both the Architectural Society of China and the Government of China. During the preparation works, "TU MU" was deleted from the Asia-Pacific Week event by SCIC (Koegel and Su 2016), since the selected architects "were not able to represent China" due to the small scale of their projects and their unlicensed status. Even after the German curators endeavored to work things out, right before the exhibition, the officials refused to ship the models with all other materials for the Asia-Pacific Week (Koegel 2019).

The unsupportive attitude from the Chinese authority is further reflected in the media reports on the exhibition in state-owned newspapers: very few reported on the event, despite its groundbreaking significance in Chinese architectural world. The only news report in *China Daily*, a national newspaper published in English, merely provided a brief introduction to all the architects and quotes from the director, the curator and the architects (Li 2001). The article was written in a neutral tone, eliminating any "inharmonious" descriptions with political implications and revealing no particular journalistic bias. The other report, which appeared in a professional newspaper *Construction Times*, was a brief introductory piece translated from the catalog preface released by Aedes (Sun 2001). Both reports revealed a cautious attitude, which might be regarded as low journalistic professionalism in a western sense. It wasn't until one year later that critical comments regarding the event emerged in a retrospective report in *New Weekly*, a newspaper published in the relatively liberal southern part of China:

A handful of experimental architects have built up a small experimental building circle, which is also a "small" force, but they really want to use their own efforts to counter the "design" of the design institute system. In the anger and disappointment brought by the ruthless construction in China's large and small cities, we may be looking forward to the difference they promised. (Huang 2002)

In contrast to the media silence in China, the exhibition was reported at length in several major newspapers in Germany, including *Frankfurter Allgemeine Zeitung*, *Berliner Zeitung*, *Frankfurter Rundschau*, and *Neue Zürcher Zeitung*. As the hallmark of western modernity and bourgeois rationality, the newspaper was still a vivid reflection of the media system in Germany at the turn of the century. Some journalists marvelled at the achievement of Chinese architects as a "revolution" (Hoffmann 2001) and criticized Chinese authority for their

"complete lack of understanding of the concept of an architectural exhibition" (Elser 2001). Others questioned the originality of the exhibited works, pointing out the obvious citations of western Modernism and calling the Chinese designs "replicas of the west". Seeing Le Corbusier in Jiakun Liu, Aldo Rossi in the works of Zhang Lei and Louis Kahn in Yungbo Chang, the critic asserts that "[the curators] show some architectural firms whose work at first glance could also stand in Rotterdam, Switzerland or even in Berlin" (Bernau and Hoffmann 2001). Either open-minded or critical, the compulsion to evoke criticality is demonstrated in the radical and opinionated tone of the journalists in the German democratic corporatist media system. Representing the interests of the German press in instigating debates and attracting audience, the newspapers successfully provided multiple interpretations of the event and ignited wide discussions on Chinese architecture, whereas little attention was aroused in China.

The Chinese and German academic circles reacted differently as well. Although all participants were affiliated to major universities in China, no relevant reports or critiques appeared in academic periodicals. "TU MU" was barely mentioned except for as a listed-overseas exhibition among other similar events. It wasn't until 2016 that the first retrospective commentary on the 2001 exhibition "the Perception of Chinese Architecture in the West: TU MU-an Exhibition at the Aedes Gallery in Berlin and its Context" written by Koegel was published in the core architectural magazine *Time + Architecture in China*. As the only scholarly article on the exhibition in Chinese, the paper recalled the preparation work, the coordination work and the success of the exhibition during its opening ceremony (Koegel and Su 2016). The exhibition, therefore, is never theorized or put into a broader historical framework in Chinese academic works. Meanwhile, although the following-up exhibition "TU MU Back Home" in 2002 brought back the whole exhibition to Shanghai with a small forum on experimental architecture, no further attention was attracted either in newspapers or academic periodicals. It was not even formally reported.

On the German side, however, a monograph on the exhibition was published by Bauwelt, one of the major architectural journals in Germany, with an introduction emphasizing the overseas educational backgrounds of the group and their disadvantaged position in the socio-political environment in China:

When young Chinese study architecture in Zurich, Darmstadt or New York and then return to the People's Republic of China, cultural-political importation is not without consequences, especially since the collective self-isolation of recent decades has brought about an all-embracing move into the private sector of planning and architectural design. (Bauwelt 2001, cover page)

Highlighting the Chinese participants as rebellions to the "collective self-isolation" in the Chinese system, the position of the monograph is controversial in itself. Out of the five thematic articles, two were irrelevant to the exhibition and sarcastically criticize the large-scale practices of foreign architects in China: the National Opera House and Beijing Jian Wai Soho. The former is described as "a student's semester homework which is less gifted than ambitious" (Edelmann 2001, 37). The overall tone of the monograph is generally conservative, underlined by a stereotypical impression of China under sweeping development. During the late 1990s to 2000, most overseas exhibitions and publications emphasized China as "the biggest construction site in Asia", e.g. Koolhaas' research "the Great Leap Forward" that investigates urban development in the Southern part of China, shown in Kassel Dokumenta, 1997; the 2G monograph on Chinese architecture which mostly reported on foreign practices in China; and the "Beijing, Shanghai, Shenzhen" exhibition held in Dessau, Germany, 2000 in which 16 out of 24 projects were designed by foreigners. The Bauwelt monograph aligns with the above literature and exhibition works despite its association with "TU MU" exhibition.

In the monograph, "TU MU"s two curators expand extensively on the social changes in China and the rise of individuality, the major prerequisites for the gradual rise of the privatized architectural studios. (Koegel 2001; Meyer 2001) Meyer discusses the emergence of "Baukultur (Building Culture)" from the former "Technokratie (Technocracy)", in which design quality will be associated with the individual architects, and, therefore, change the anonymous state of designers in state-owned design institutes. Koegel emphasizes the pedagogical reforms in new architectural programs as sites for architects to form a new community, to receive on-grounds commissions and to present themselves as public intellectuals. In either article, no specific terms were articulated to describe the practices of this group of architects. While the curators excessively analyze the political, social and institutional conditions for new practices to thrive, neither are capable of positioning the architects in the larger framework of world architectural culture, or identifying the design language of the exhibited works, either in China or in the western world.

The avoidance of the group in Chinese academic circles and the controversial emphasis on their socio-political stance in the German critiques indicate that the so-called "Young Architecture of China" was not a mature, self-aware practice back in 2001. In the catalog of the exhibition, the practices of the first privatized Chinese studios are referred to as "alternative positions" (Koegel and Meyer 2001, 12) and "a kind of "hybrid" architecture, which combines historical types with new

impulses from the West, (Koegel and Meyer 2001, 15) and played with vague notions of defining the group as rebellions to the mainstream system. As is asserted by Bourdieu, "the struggle defines the author" in a western sense (Bourdieu 1993, 42). Given the historical fact that none of the participants were licensed, that most of the studios were established only one or two years before the exhibition and very few projects were built, the exhibition reflects the intentions of the German gallery to construct a manifesto that promotes and consolidates an emerging practice. It was not a faithful reflection of the urban and architectural developments in China, but rather advocacy to raise attention in the West and open up new discussions for the future.

The title "TU MU: Young Architecture of China" is ambitious in the German context, but also reveals the asymmetrical perceptions of the theme between the Chinese and German sides. As mentioned by the curator, the organizers of the exhibition abandoned the existing Chinese term "experimental architects", which was used to describe the group in a 1996 forum in Beijing, in order to "free it from the experimental situation" and cause "bigger impact" (Koegel 2019). On the Chinese side, the same message was lost in translation as the Chinese title "TU MU: Young Architects from China (Tumu: Zhongguo Qingnian Jianzhu Shi)" merely indicates the age level of the participants. "TU MU", or "Earth and Wood" in Chinese, was carefully chosen by Yungho Chang as the major title of the exhibition to emphasize the relationship to traditional building aesthetics (Koegel 2016), yet this was barely explained in the introductory paragraph of the catalog. In the director's words, "earth and wood" represented the past, which is no longer of concern in the new developments of Chinese architecture:

That wood and earth are no longer being used in China's metropolises, as the poetic title of this exhibit suggests, we have known for quite some time now. But the dimensions, socio-political background, and above all the dynamics with which architecture and urban design develop themselves in China are difficult to comprehend for us in Europe. (Feireiss and Commerell 2001, 1)

With a strong urge to push forward the architectural discourse, the general tone of the texts in the gallery's official documents is affirmative and even assertive. The press release defines the exhibited works as "the first promising hints for the development of an independent architectural language" (Aedes 2001, 1), and the curator powerfully asserts that "in terms of architectural aesthetics and conception, the young Chinese designers have arrived at the heart of the contemporary debate on architectural culture" (Koegel and Meyer 2001, 15). These texts reflect the intentions of the German institution to launch a discourse with the exhibition, despite the immature state of practices back in China.

Overseas Exhibitionary Events as the Dictator of Contemporary Chinese Architecture

The gallery brands itself as “synonymous with the great names in the world of architecture by continuously supporting new generations of upcoming practitioners” which has presented the works of “[m]any internationally acclaimed architects and Pritzker Prize Laureates... long before achieving international fame” (About 2019); thus the narrative constructed by the German gallery director and curator coincides with the goal of promoting architectural discourse. The exhibition proved to be a great success, with many German scholars and critics astonished by the exhibited works (Koegel and Su 2016). The event thereafter triggered a long-term cooperation between Chinese architects and the gallery resulting in four exhibitions from 2003 to 2007, and eight exhibitions from 2015 to 2019. The 2016 “ZAI XING TU MU (Reviving Earth and Wood): Sixteen Chinese Museums, Fifteen Chinese Architects” exhibition directly reflects the impact of the 2001 exhibition. Again in an assertive tone, the press release of the exhibition emphasizes “TU MU” as the catalyst for Chinese architects’ success in practice and in academic circles:

To our surprise we found out many years later, that the TU-MU exhibition ignited an intense and controversial discussion within China on architecture, building culture, identity, tradition and modernity. Today TU-MU is a synonym for an awakened and enforced self-consciousness and independency in Chinese contemporary architecture. (Aedes 2019)

In 2018, the director of Aedes discussed profusely the 2001 exhibition in an interview, again emphasizing the decisive role of the event in inaugurating an era for the recognition of independent Chinese architects in the European context (Commerell 2018). Compared to the German gallery’s enthusiastic references to “TU MU” as its own successful discovery of novel and diverse practices, the Chinese architects, critics and curators showed little interest in reflecting on the 2001 exhibition.

Judging from the above analysis, with an underdeveloped, unsupportive media industry and low instinct for publicity, the independent architects in China were not capable of establishing a coherent discourse by themselves. Placed in an alien context, the scattered, unorganized and underrepresented architects were assembled and edited into a powerful narrative by a strong, mature and liberal media system. The event, therefore, facilitated the worldwide recognition of the group, while consolidating the image of contemporary Chinese architecture in a Euro-centric context. It is worth noting that none of the Chinese architects presented their works in their own words at the opening ceremony or participated in the writing or editing of the catalog, the press release or the journal monograph. Their only presentations took place during the symposium one day before the opening, which was poorly documented with

no photos or records remaining. The voicelessness of the Chinese participants, despite their position in the exhibition as “protagonists”, questions the authorship and subjectivity of the constructed narrative. With most historical texts reflecting the interests of the German institutions, press and academic circle, the exhibition is emerged from the interests of the German organizers, despite its intention of supporting the Chinese architects. Further, as the first overseas exhibition that aroused great European attention towards contemporary Chinese architecture, the narrative constructed from unspoken power relations is not only problematic in itself but has also further influenced subsequent exhibitionary events, as well.

4. PROBLEMATIZING THE CONSTRUCTED DISCOURSE

Organized by a German curator and held in a German gallery, “TU MU” constructed an image of the rebellious, uncompromising Chinese architects as promising future leaders in architectural culture. The issues of how the group was perceived at home, how they got commissions, how much of the market they occupy, whether they intended to make social changes and whether they represented an expanding force or a small circle of elite intellectuals are irrelevant. In a postmodern world, knowledge must be packaged into media formats in order to be produced and disseminated, and those with the ability to sort through the vast amounts of information and repackage it with meaning decide on the current version of the “truth” (Lyotard 1984, 5-6). The legitimization of knowledge is, therefore, determined by the intertwining forces of power, authority and media approaches. “A narrator attains legitimation simply by being the narrator” (Lyotard 1984, 21-22). As the first overseas exhibition for Independent Chinese architects in Europe, “TU MU” constructs the criteria for contemporary Chinese architects to be selected. The exhibitionary event played a determining role in initiating a Euro-based discourse in which the practitioners could identify themselves.

The German intention of breaking through stereotypes and promoting diversity presumes itself as the decision maker empowering disadvantaged groups in the world culture system. As Said notes in *Orientalism* (1979), “they (the Orientals) cannot represent themselves. They must be represented” (Said 1979, xii). Based on the Foucaultian analysis of knowledge production, Said argues that it is necessary to “examine Orientalism as a discourse”... and “because of Orientalism the Orient was not (and is not) a free subject of thought or action” (Said 1979, 10). In the case of “TU MU”, the Chinese designs are described as a Western projection, which can only be communicated either through comparison or

contrast with European Modernism. The German critics marvelled at Chinese “achievements” in design qualities resembling European buildings that “qualifies” them to “enter the heart of contemporary debate on architectural culture” (Koegel and Meyer 2001, 15), and interpreted the “Chinese traditional elements” as an exotic, mythic oriental aesthetics frozen in time. The so-called modern or traditional, political or cultural, regional or global positions of the Chinese architects all depended on the media infrastructures and value systems of the West.

Further, as Said failed to address, the process was not accomplished solely by the European side. Third-world countries, including China, contributed equally to European cultural imperialism in the world history equating Europe with “modernity”. As the non-mainstream architects were legitimized in the exhibition, their careers boomed at home in the years following, and the group expanded as younger generations sought to emulate this “big success story” (Koegel 2019). The formerly suppressed group not only became dominant in the marketplace but was also recognized as authorized to represent the national image in international cultural events, starting with the 2006 Venice Biennale. The narrative, therefore, goes far beyond theoretical discussions and debates on paper, but in turn dictates the perception of architectural culture and the commissioning of real-world projects back in China.

While independent Chinese architects flourished as representatives of contemporary Chinese visual culture (Architectuurinstituut 2006), few ever reflected on the fact that the discourse was built upon a transnational

exhibitionary event with almost a complete absence of Chinese voices. Although the circumstances of authorship and subjectivity have changed over the years with the increasing status of contemporary Chinese architects in the world, the same criticality and self-identification is repeated over and over again and consolidated as the underlining characteristics of the discourse. The events construct a “field”, a “separate social universe”, an area of the social world characterized by hierarchical organization, by internal relations of force, and by regulatory mechanisms that assesses cultural production in certain classificatory principles, as the Bourdieuvian notion of “habitus” (Bourdieu 1993, 162; Bourdieu 1990, 12-13).

After the success of “TU MU”, subsequent exhibitions in European countries basically invited the same group of people, instead of researching new ones, as “the circle of architectural discourse needs only a few protagonists” (Koegel 2019). The field of architectural production brings prestige, fame and financial rewards. On the one hand, more architects are attracted to follow the successful models, resulting in less media exposure of the “alternatives of the alternatives” and less diversity in practice; on the other hand, with a handful of established architects dominating the field, less space is left for the younger generations to be recognized, either at home or in the world. Therefore, the narrative started by “TU MU” not only defined the contemporary Chinese architecture in a displaced context, but also continues to dictate the ecology of contemporary Chinese architects, despite the changing social and financial status of the group today.

REFERENCES

- Aedes Architecture Forum. 2019. “About Aedes,” Aedes-arc.de. <https://www.aedes-arc.de/cms/aedes/about>
- Aedes ANCB Program. 2019. “Pre-Announcement for the Press: Zai Xing Tu-Mu Museum Fifteen Chinese Architects.” <https://stadtmacher4986.com/>
- Aedes East Forum. 2001. “Press Release “TU MU—Young Architecture from China.” Berlin: Aedes East Forum.
- Anderson, Benedict. 2006. *Imagined Communities: Reflections on the Origin and Spread of Nationalism*. New York: Verso books.
- Ang, Ien. 1990. “Culture and Communication: Towards an Ethnographic Critique of Media Consumption in the Transnational Media System.” *European Journal of Communication* 5, no. 2: 239-260.
- Architectuurinstituut, Nederlands. et al. 2006. *China Contemporary: architectuur, kunst, beeldcultuur/China Contemporary: Architecture, Art, Visual Culture*. Rotterdam: NAI.
- Bernau, Nikolas, and Hans Wolfgang Hoffmann. 2001. “China als Abziehbild des Westens: Aedes zeigt und ein Symposium diskutiert erstmals Arbeiten chinesischer Privatarchitekten im Westen.” *Berliner Zeitung*, September 27th 2001.
- Bourdieu, Pierre. 1990. *In Other Words: Essays Towards a Reflexive Sociology*. Stanford: Stanford University Press.
- Bourdieu, Pierre. 1993. *The Field of Cultural Production: Essays on Art and Literature*. New York: Columbia University Press.
- Commerell, Hans-Juergen. 2019. “Interview.” *Aedes Architekturforum Archive*.
- Dayan, Daniel, and Elihu Katz. 1992. *Media Events*. Cambridge: Harvard University Press.
- Donsbach, Wolfgang, and Bettina Klett. 1993. “Subjective Objectivity. How Journalists in Four Countries Define a Key Term of their Profession.” *Gazette (Leiden, Netherlands)* 51, no. 1: 53-83.

Overseas Exhibitionary Events as the Dictator of Contemporary Chinese Architecture

- Edelmann, Friedrich. 2001. "Das Ei von Peking: Chronik eines französischen Exportartikels." *Bauwelt* 35: 37-29.
- Feireiss, Kristine, and Hans-Juergen Commerell. 2001. "Preface." In *Tu Mu: Young Architecture of China: Ai Wei Wei, Atelier Feichang Jianzhu, Liu Jiakun, MRMADA, Wang Shu, Nanda Jianzhu*, 1-2. Berlin: Aedes East Forum.
- Hallin, Daniel C., and Paolo Mancini. 2004a. "The North/Central European or Democratic Corporatist Model". In *Comparing Media Systems: Three Models of Media and Politics*, 143-197. Cambridge: Cambridge University Press.
- Hallin, Daniel C., and Paolo Mancini. 2004b. "Introduction". In *Comparing Media Systems Beyond the Western World*, 1-6. Cambridge: Cambridge University Press.
- Hoffmann, Hans Wolfgang. 2001. "Bausteine einer Revolution." *Frankfurter Rundschau*, September 27th 2001.
- Huang, Jingjing. 2002. "Revisiting the 'TU MU: Young Architects of China Exhibition, Berlin'" *New Weekly* 3.
- Elser, Oliver. 2001. "Schillernde Grauzonen im Schatten der westlichen Anmutung." *Frankfurter Allgemeine Zeitung*, September 25th 2001.
- Foucault, Michel. 1972. *The Archaeology of Knowledge*. Translated by AM Sheridan Smith. New York: Pantheon Books.
- Jacques, Martin. 2012. *When China Rules the World: The Rise of the Middle Kingdom and the End of the Western World [Greatly updated and expanded]*. London, UK: Penguin.
- Klauser, Wilhelm. 2001. "Ein Japaner in China: Das Beijing Jian Wai SOHO." *Bauwelt* 35: 34-36.
- Koegel, Eduard. 2001. "Die Einheit Loest sich Auf." *Bauwelt* 35: 16-17.
- Koegel, Eduard. 2019. "Personal Communication". Interview by Dijia Chen, March 6, 2019.
- Koegel, Eduard, and Ulf Meyer. 2001. "Positions far from the Architectural Crowd." in *Tu Mu: Young Architecture of China: Ai Wei Wei, Atelier Feichang Jianzhu, Liu Jiakun, MRMADA, Wang Shu, Nanda Jianzhu*. Berlin: Aedes East Forum, 12-15.
- Koegel, Eduard, and Ulf Meyer. 2001. "Sechs Beispiele aus sechs jungen Büros". *Bauwelt* 35: 20-33.
- Koegel, Eduard, and Hang Su. 2016. "The Perception of Chinese Architecture in the West: TU MU—an Exhibition at the Aedes Gallery in Berlin and its Context". *Time Architecture* 2: 26-30.
- Lee, Richard E. 2010. "Critiques and Developments in World Systems Analysis: An Introduction to the Special Collection." *Journal of Philosophical Economics* 4, no. 1: 5-18.
- Li, Xiangning. 2001. "Spirit of Earth and Wood Lives On: Young Talents Bring New Perspective to China's Modern Architecture." *China Daily*, August 10, 2001.
- Li, Xiangning. 2014. "Architecture as a Resistance—Wang Shu and his Architecture". *World Architecture* 8: 30-31.
- Lyotard, Jean-François. 1984. *The Postmodern Condition: A Report on Knowledge*. Vol. 10. Minneapolis: University of Minnesota Press.
- McChesney, Robert W. 2001. "Global Media, Neoliberalism, and Imperialism." *Monthly Review* 52, no. 10: 1-19.
- McChesney, Robert W., John Bellamy Foster, Inger L. Stole, and Hannah Holleman. "The sales effort and monopoly capital." *Monthly Review* 60, no. 11 (2009): 1.
- McLuhan, Marshall, and Quentin Fiore. "The Medium is the Message." *New York* 123 (1967): 126-128.
- McQuail, Denis. 1987. *Mass Communication Theory: An Introduction*. New York: Sage Publications.
- Meyer, Ulf. 2001. "Die Neuerfindung des Architekten: Vom Technokraten zum verantwortlichen Entwerfer." *Bauwelt* 35: 18-19.
- Rao, Xiaojun. 2000. "Experimental Architecture: A Conceptual Exploration." *Times Architecture* 2: 12-16.
- Said, Edward. 2014. "Orientalism". In *Geopolitics*, 75-79. London: Routledge.
- Schramm, Wilbur. 1964. *Mass media and National Development: The Role of Information in the Developing Countries*. Vol. 25. Stanford, CA: Stanford University Press.
- Sun, Tian. 2001. "Chinese 'TU MU' Staged in Berlin." *Construction Times*. October 12, 2001.
- Tiez, Juergen. 2007. "Zwischen Aufbruch und Ruckbesinnung: Junge Chinesische Architekten in Berlin." *Neue Zürcher Zeitung*, October 6th 2007.
- Wallerstein, Immanuel. 2008. "The Modern World-System as a Capitalist World-Economy." *The Globalization Reader*: 55-61.
- Wang, Mingxian, and Jian Shi. 1998. "Chinese experimental architecture in the 1990s." *Literature & Art Studies* 1: 118.
- Zhao, Yuezhi. 2012. "Understanding China's Media System in a World Historical Context." *Comparing Media Systems Beyond the Western World*: 143-176.
- Zhao, Y. and D. Schiller. 2001. "Dances with Wolves? China's Integration into Digital Capitalism." *Info* 3 (2): 137-151.

Abstract: Current historiographical discourse on Richard Neutra's designs and professional trajectory constantly repeat assessments that express the strangeness regarding some aspects of his works. With that in mind, and after identifying those aspects, the purpose of this paper is to present an analysis on Neutra's designs from a different point of view: one that acknowledges his connections with Latin American architects and identifies in those strangeness the reflections of this relation.

The first step was to understand the historical background, Neutra's trip to South America and connections established there, and United States' political situation of the time. After that, the systematic reading of the main studies/books on Neutra revealed a gap in the understanding of his works, or even a lack of a more focused analysis in some aspects of his designs. By changing the point of view and, also, by looking to those strange aspects with a closer attention, new interpretations can be made that consider Neutra's trajectory in all its particularities, including the relationship established with Latin America. The result is a possibility for new discussions on the architect's legacy and a contribution to the historiographical discourse.

Keywords: Richard Neutra, Latin America, design, connections, historiographical discourse

INTRODUCTION

Richard Joseph Neutra (1892-1970) is a well-known Austrian-American architect. His pre and post Second World War designs are recognized by historiographical discourse throughout the world. In Latin America, for example, magazines from São Paulo (e.g. *Pilotis*, *Habitat*, *Acrópole*), Rio de Janeiro (e.g. *Módulo*), and Buenos Aires (e.g. *Nuestra Arquitectura*) constantly published his works, especially the Californian houses and the schools, hospitals, and health centers designed for Puerto Rico. Furthermore, four of his books were published in Latin America: The bilingual publications (Portuguese and English) *Arquitetura Social em Países de Clima Quente/Architecture of Social Concern in Regions of Mild Climate* (São Paulo, 1948) and *Neutra: Residências/Residences* (São Paulo, 1951); the Spanish translations *Planificar para Sobrevivir* (Mexico, 1957) and *Vida y Forma* (Buenos Aires, 1972); and *Realismo Biológico*, and *Un Nuevo Renacimiento Humanístico en Arquitectura* (Buenos Aires, 1958), published only in Spanish.

Other important books, written by Neutra himself and by renowned researchers (like Willy Boesiger, Bruno Zevi, Manfred Sack, and Esther McCoy), were published while the architect was still alive and active, but all of them suffered from the imposing presence of Richard Neutra in their narrative. It was only with the compendium *Richard Neutra: Complete Works*, edited by Barbara Lamprecht, and with Thomas Hines' biography *Richard Neutra and the Search for Modern Architecture* that a wider and critical discussion of his designs and professional trajectory was initiated. From this point on, almost all research on Richard Neutra carries in its core

the *truths* established by them, even the most recent work developed by David Leatherbarrow and Catherine Ettinger. There is also discussion, based on Neutra's theory, on a psychoanalytic architecture (in other words, the impact of architecture on the life and health of its inhabitants), like the studies by Sylvia Lavin and Todd Cronan. For the purposes established in this paper and in the author's dissertation research, however, the focus will be on the elements of the architecture developed by Richard Neutra.

At first glimpse, to base one's research on work done previously should not reflect a problem or matter for further discussion. As Marina Waisman once said, historiography is not a mere historical report. It has embedded in it the historian's ideological point of view. Therefore, it is our job as researchers to question and to propose new interpretations of the historical fact, be it of a document or even a work of built architecture.

The historical problems are solved by the research. Critical operation is performed to ensure data accuracy and relevance. They are technical problems. On the other hand, the historiographical problems are directly tied with the historian's ideology, because they delimit their object of study and critical instruments to define the historiographic text structure. Then, all these tools will lead to interpretation of facts and to the formulation of the chosen subject through their own point of view. (Waisman 2013, 5. Author's translation)¹

With that assessment in mind, the goal of this paper, and by extension the author's doctoral research, is to enlighten some aspects of Richard Neutra's work and professional trajectory that were neglected or taken

as strange facts by the existent historiographical discourse. In other words, after having identified those aspects in the historians' speech, especially the ones concerning the architect's relations with Latin America, it becomes clear that new interpretations are needed. A similar document—being it a historical document, a written contribution (books, newspapers and magazine articles) or architecture (as a built document)—can give different answers depending on the new questions that are made (Zein 2019). In the specific case of this paper, new questions and new interpretations arise from a different point of view, one that originates in Latin America. Therefore, the purpose of this paper is to collaborate with a critical discussion about an important twentieth-century architect and, with that, enrich the current historiographical discourse.

1. RICHARD NEUTRA AND LATIN AMERICA

1.1. THE 1945 VISIT OF SOUTH AMERICAN REPUBLICS

Richard Neutra's relation with Latin America strengthened in 1945 when he was designated by the Division of Cultural Cooperation of the U.S. Department of State to travel through the countries South of the Grande River.² As a part of the Good Neighbor Policy, established by President Franklin Roosevelt, Neutra's cultural mission was to give "Latin American architects a better understanding of architecture within the United States" ("Letter from Charles W. Collier" 1945, 2).

In the two month period that he travelled through South America, Neutra visited Guayaquil, Ecuador; Lima, Callao, San Miguel, Magdalena, San Isidro, Miraflores, Rimac, and Arequipa, in Peru; La Paz, Bolivia; Buenos Aires, Argentina; Montevideo, Uruguay; Porto Alegre, São Paulo, Guarujá, Santos, Rio de Janeiro, Niterói, Petrópolis, Belo Horizonte, Ouro Preto, Barreiras, Carolina, and Belém, in Brazil.³ In each one of these cities, he met with government authorities, intellectuals, and local architects. He also gave lectures at universities and institutes of architects and attended dinners at United States ambassadors' homes. More importantly, he visited iconic Latin American projects (Guerra and Critelli 2013; Critelli 2015).

In summing my experiences, I believe that apart from the customary social meetings, considered useful to make for good will, my procedure to make the problems of the visited city itself the subject of formal lectures, round table discussions and broadcasts, proved very satisfactory and was well received. It naturally requires a speedy way of gathering the necessary information, but in many cases, it yielded, according to my local friends, truly constructive publicity and appreciation of the State Department's cultural cooperation effort. ("Report on visit South American Republics" 1946, 1)

Despite fulfilling a diplomatic mission, Neutra found in Latin America interlocutors for his quest in architecture, its relation to climate, landscape, and local construction technology. Not only did he connect with his fellow architects, but he also studied and admired their designs and projects. In October 1946, Richard Neutra wrote an article, published by the magazine *Progressive Architecture*, entitled "Sun Control Devices" (Neutra 1946b). In it, he presented North American readers a study of the answers given in architecture for sunlight control, based primarily on South American examples he had visited and photographed. He states, "No other single feature of South American architecture has excited as much attention as the conspicuous means of controlling sunlight which characterize the buildings. Vertical, movable louvers are particularly intriguing to me because a decade ago I experimented with this type of device, although I did not pursue my ideas to an ultimate conclusion" (88).

However, it was not only the photographs and sketches made during his trip that Neutra brought back to the United States with him. The friendships and professional connections established there were extremely important and would last for years to come. That is the case, for example, of his relationship with Brazilian landscape designer Roberto Burle Marx.⁴ They met for the first time in November 1945 and then, again, in 1952 at the Aspen Conference, which Raymond Neutra, the youngest son of Richard Neutra, also attended, as well as a picnic that his family had along with Burle Marx. After those two encounters, a series of letters, archived at UCLA, connected them both-between August 1954 and September 1956, eighteen letters were exchanged. By reading them, one can acknowledge an important historical fact: Neutra offered Burle Marx a partnership in four projects: the Richard Hammerman House (West Los Angeles, 1954, artistic panel, never built), Sidney and Sonja Brown House (Bel Air, 1955, landscape, never built), Amalgamated Clothing Workers of America Building (Los Angeles, 1956, artistic panel and landscape, built), and Alfred De Schulthess House (La Habana, 1956, landscape, built) (Critelli 2015, 173-271). In fact, analyzing these documents makes clear that Neutra not only offered his colleague the partnerships, but insisted to his clients that they hire the Brazilian landscaper.

1.2. THE ARCHITECTURE ROLE IN U.S. FOREIGN POLICY

America began as an empire during the nineteenth century, but it was in the second half of the twentieth, after the decolonization of the British and French empires, that it directly followed its two great predecessors. (Said 1994, xxii-xxiii)

The U.S. diplomatic policy and its cultural approximation efforts are subjects of academic discussion from North to South. To cite just a few researchers: Gerson Moura (1984 and 2013), Antonio Pedro Tota (2000 and 2014), Luis Alberto Bandeira (1973), Fernando Atique (2010), Lauro Cavalcanti (2006), and Carlos Minchillo (2015), in Brazil; Jorge Francisco Liernur (1998 and 2010), in Argentina; Anaioly Glinkin (1990), in Russia; Michael Blumenthal (1968), Patrício Del Real (2012), Thomas Leonard (1999), Justin Hart (2013), Jenifer Van Vleck (2013), Gisela Cramer and Ursula Prutsch (2012), in the United States. However, most of these researchers focus on the efforts of continental approximation through the arts (e.g. cinema and literature) and economic cooperation. It is only Patrício Del Real who studied the consequences of U.S. foreign policy on Latin American architecture.

As pointed out by Edward Said, in the previous epigraph, the United States of America's project for becoming an empire initiated in the nineteenth century with the Monroe Doctrine, as it was latter known President James Monroe's protectionist policy toward the American continent, and was consolidated after the Second World War, with the devastation of Europe. During the first half of the twentieth century—amidst the economic, territorial, and ideological impacts of the war—President Franklin Roosevelt realized the necessity for a softer, more diplomatic foreign policy (Hart 2013). Therefore, instead of adopting policies of direct intervention (like the Big Stick or the Dollar Diplomacy), he opted to unify and protect the American continent using subtle forms of domination and ideological influence over Latin America (Lübken 2012, 63).

In order to achieve North American goals, the U.S. State Department (especially the Cultural Cooperation Division) and the Office of the Coordinator of Inter-American Affairs—OCIAA (coordinated by Nelson Rockefeller throughout most of its existence) organized a series of cultural exchange and aid programs. Among them: the 1940 MoMA exhibition of Brazilian painter and muralist Cândido Portinari; the 1942 trip through South America of Walt Disney and his crew of artists; that resulted in the creation of the characters Zé Carioca (representing Brazil) and Panchito (representing Mexico); the City of Motors, designed in 1942 by Josep Luis Sert and Paul Lester Wiener; the participation of Brazilian architect Oscar Niemeyer on the team led by Wallace Harrison for the design of UN headquarters; and also the 1945 diplomatic mission through South America undertaken by Richard Neutra (Critelli 2015, 47-114).

In addition to cultural programs, in that period of international conflicts modern architecture became a symbol of prosperity and possibility for a better future.

This *appropriation* was designated by historian Ron Robin as “political architecture”.

Political architecture, a symbolic illustration of American power and willingness to intervene forcefully in the theater of international relations, played a significant role in the complex mission of orchestrating world affairs while refraining from an enduring and large physical presence abroad. Thus, an analysis of the symbolism of American architecture abroad reveals the crystallization of fundamental American goals in the international arena. (Robin 1992, 5)

In this sense, the constructions of embassies and consular buildings abroad—always a way of imposing one country's presence over another—was considered by President Roosevelt as essential for implementing the foreign policy he intended (Robin 1992, 92-93). By 1946, after Congress had approved the use of *frozen assets* for construction of new embassies and consular buildings, the Foreign Building Operation (FBO) established headquarters in Paris, Haia, London, Bonn, Tokyo and Rio de Janeiro (in addition to the original in Washington), and designated supervisors for East Europe, North Africa and Middle East (Loeffler 2011, 37). Leland W. King Jr., architect and director of FBO, began to invite famous architects to develop embassy designs. With that initiative, between 1948 and 1958, the program gained the reputation as a showcase of modern architecture (Loeffler 2011, 57).

For the embassies in Rio de Janeiro (1948-52) and La Habana (1950-52), King hired Harrison & Abramovitz, a well-known architecture office that was responsible for, among other projects, the construction of the UN headquarters in New York. The choice of Wallace Harrison for these two designs does not seem to be coincidental. The architect was deeply embedded with United States' foreign policy and already had the experience of working in Latin America. He was the architect, for example, of the Avila Hotel (1941), in Caracas, and U.S. Air Base (1942), in Panama. Furthermore, in 1945, he was named Chief of the Cultural Affairs Division of the OCIAA, where he worked under Nelson Rockefeller's leadership. In spite of Jane Loeffler's affirmation in her book *The Architecture of Diplomacy* that the architect was chosen only for his merit and architecture ability, it is impossible to ignore the importance of personal relations between Harrison and Rockefeller in this case. As Garry Stevens would say, upper class individuals have a broader network of acquaintances that can be helpful in business (Stevens 2003, 77).

In 1955, the United States Congress approved a budget of three million dollars to be spent for embassy construction, half of which was for the “construction of an impressive new chancery in Karachi” (Loeffler 2011, 41). For that job, the FBO hired the office of Neutra

& Alexander. According to Thomas Hines, this was the third most-important project of the partnership, alongside the Lincoln Memorial Museum Visitor Center and the Los Angeles County Hall of Records (Hines 2005, 88). Completed in 1959, the U.S. Embassy in Karachi was designed to attend to the local needs of climate, materials, and labor conditions (Lamprecht 2012; Loeffler 2011, 174). Even though Hines referred to it as an important design of the Neutra and Alexander partnership, the historian also described it with strangeness as a result of the disagreements between the two men.

2. THE STRANGE IN THE WORK OF RICHARD NEUTRA

2.1. THE HISTORIOGRAPHICAL DISCOURSE

After reviewing Richard Neutra's trajectory (graduation, moving to the United States, his designs, and, especially, his relationship with Latin America) and the historical background of the time (political, economic, and cultural relations between United States and Latin America and the war in Europe)—i.e. the micro and macro histories—it is possible to launch new interpretations of Neutra's works and of the historiographical discourse available about him. When one does that, it becomes clear that some aspects were dismissed as *strange* by historians—starting with Hines and Lamprecht, up to the more recent José Vela Castillo and Catherine Ettinger.

The first step here is to understand the meaning of the term *strange*.⁵ To help with that, we will take under consideration a definition elaborated by Sigmund Freud, when studying psychoanalysis through literature examples:

The German word *unheimlich*⁴ is obviously the opposite of *heimlich*, *heimisch*, meaning "familiar," "native," "belonging to the home"; and we are tempted to conclude that what is "uncanny" is frightening precisely because it is not known and familiar. Naturally not everything which is new and unfamiliar is frightening, however; the relation cannot be inverted. We can only say that what is novel can easily become frightening and uncanny; some new things are frightening but not by any means all. Something has to be added to what is novel and unfamiliar to make it uncanny.. (Freud 1919, 2)

Relating this concept to the discussion established here about Richard Neutra, the *new* proposed by the architect in some designs brought *something* that made his projects *strange* and *unfamiliar* to these historians. If we change the point of view in the historiographical discourse, (i.e. from South to North) then it might be possible to realize that this *something* would be the relation between Neutra and Latin America. A manifestation that bothered some historians, causing them to react against it with strangeness. According to Freud, *unheimlich* is everything "that ought to have

remained hidden and secret, and yet comes to light." (Freud 1919, 4).

It is not the intention of this paper to point out mere influence or mimicry of the Latin American designs in Neutra's works. After all, he was already a mature and established architect long before his first visit of 1945. However, as an architect that "empirically observed all his life" (Lamprecht 2012), it would be wrong to assume that his several visits, the connections established there and the projects that he not only saw, but also photographed and studied, did not have an effect on his latter designs. As it happens in poetry and in paintings, to observe, to read and to interpret another artform gives the person in question the power of an acting agent that chooses its influences and generates a distorted interpretation of it (Bloom 1997; Baxandall 1985).

Thomas Hines' biography on Richard Neutra was the first dense, critical, and prolific study published about the architect. Therefore, it is a reference quoted in the research conducted thereafter. However, as any historiographical discourse, it is not exempt from ideological positioning and should not be repeated without judgement or critical review (Waisman 2013). Therefore, this paper seeks to decipher aspects of Neutra's works that were described as strange and not in tune with what historians considered Neutra's designs in their pure form. This phenomenon happens not only with Hines, but with other historians as well. Another phenomenon this paper intends to highlight is the indiscriminate repetition of conclusions, made first by Hines and/or Lamprecht, without any kind of review, not even by Latin American researchers.

Not only the *strangeness* was repeated. There are a couple of projects that Neutra considered important in his professional trajectory, that were—deliberated or unconsciously—neglected by Hines and Lamprecht, and consequently by recent researchers. In all those cases, new interpretations are possible. However, for the purposes of this paper, we will focus only on two examples where we detect the strangeness in the historian's discourse. Keeping in mind the impact and importance that the connections with Latin America had in Neutra's designs—an importance shamelessness admitted by him—it is possible to interpret the strangeness detected in a different manner.

2.2. THE STRANGE DESIGNS

Los Angeles Hall of Records

Alexander's penchant for warming Neutra's stark modernity with *colorful*, *organic* artwork led to cacophony on the building's North façade and to mixtures of too many competing and incompatible materials elsewhere. (Hines 2005, 268)

In his brief analysis of the Los Angeles Hall of Records, Thomas Hines blamed the building's final aesthetics on the constant disagreements the partners were having, as if each one of them could be responsible for a minor part of the design. Moreover, he based his assumption on the interviews that Robert Alexander gave after Neutra's passing.⁶ However, earlier in his book, Hines points out that a clear division of functions was established between them: Neutra was in charge of the final decisions in architecture design, and Alexander of the urban designs (Hines 2005, 255). If there is truth in what Alexander said regarding Neutra being a tyrant in his own office, always seeking ways to make himself immortal (Hines 2005, 268), is it possible to say that a design could be approved and built against Neutra's wishes?

Furthermore, there is another aspect that is missing from Hines' discourse: Neutra's intense transit and relation with Latin American architecture of the time. As it was briefly discussed earlier in this paper, the United States fear of European control over the American continent led them to increase efforts for continental unification and assistance. Within this foreign policy, programs of cultural exchange introduced to North Americans the works of such artist and muralists as Brazilian Cândido Portinari and Mexican Diego Rivera,⁷ both of them whom Neutra met in person.

For a better understanding of the use of artistic panels in Brazilian modern architecture, a parenthesis with architecture historian Roberto Segre's assessment is necessary, "the *Brazilian* expression of European rationalism heritage [...] is the presence of chromatic or figurative panels on building's ground floor walls: They appear on Cândido Portinari's azulejos for MES [Ministry of Education and Health]; or on the persistent collaboration of Athos Bulcão in the designs of national capital's initial construction: e.g. Brasília Palace Hotel (1957)" (Segre 2009, 168. Author's translation).⁸

It is also important to recall the professional relationship between Richard Neutra and Roberto Burle Marx. As evidenced in the author's master thesis. Of the four proposed designs in the partnership, two of them were landscape designs—Brown House (1955, not built) and De Schulthess House (1956, built)—while the other two were artistic panels—Hammerman House (1954, not built) and Amalgamated Clothing Workers of America building (1956, built) (Critelli 2015). There could be many reasons for not executing the house panel, but the documents make clear that Neutra was insistent with his clients about the importance of building such panels and, especially, about the importance of hiring Burle Marx to design them (Critelli 2015). If these situations really happened, then one can imagine that the same thing happened in the process of designing the panel on Los Angeles Hall of Records. In other

words, Neutra's interest and effort in integrating the arts in his works can be a clue to understanding that the 80-foot glass mosaic, designed by Joseph Young, was integral to his plans for the building.

Deploying Sigmund Freud's concept, the artistic panel caused strangeness in Hines. For him, it was unfamiliar in the overall designs of the architect, not for being new—as it was not—but because it manifested something that Hines preferred would stay hidden. This manifestation was in fact the expression of a close relationship with Latin American architecture that was deemed strange by Hines. To explain the *new* and *strange* in Neutra's work, Hines blamed Robert Alexander and the constant disagreements between the partners.

There is another interesting aspect of the Los Angeles Hall of Records project that is not matter of discussion for Hines, but, when it appeared on another design, caused strangeness: the 125-foot-high movable aluminum louvers used to protect the South-West façade. The element was extensively studied by Richard Neutra for this project in particular, and also for his post-1945 designs. Over all, there are twenty designs where Neutra used this element for solar protection—in its fixed, movable, vertical, and horizontal versions. Despite the recurrence, José Vela Castillo called it a "technological exhibitionism" when analyzing the VDL II House (Castillo 2003, 95). The movable louvers are, in fact, a striking element in the design. However, they are far from being exhibitionism of any kind, but rather represent the architect's ability to work with external influences—Neutra's article "Sun Control Devices," written in 1946 for the magazine *Progressive Architecture*, stands as proof. It is exactly the fact of presenting an influence and connection with Latin American architecture that elicited the reference to strangeness in Castillo's discourse.

United States Embassy in Karachi

In the new American Embassy in Karachi, West Pakistan, monumental modernism seemed the order of the day. Commissioned as one of a series of new embassies by distinguished American architects, the Karachi building was to take its place in the parade of monuments that would ultimately include Edward Stone's building for New Delhi, John Warneke's for Bangkok, Walter Gropius' for Athens, and Eero Saarinen's for London. [...] Alexander learned while visiting Karachi of the ready availability of cylindrical molds for casting concrete vault forms, and was determined to utilize such forms in an effort to counter what he believed to be Neutra's overly stark design of the main administration wing. The result was a meaningless series of equally bland vaults used to decorate the façade of the rear warehouse storage wing. Though it was no better or worse than most of its sister embassies in the fifties, the lack of resolution in the Karachi building illustrated sadly the unresolved tensions of fifties modernism in general and of the Neutra & Alexander partnership in particular. (Hines 2005, 266-267)

There are many aspects of Hines' statement that deserve attention. The first is related to the program of building embassies abroad. Recalling the brief discussion established earlier in this paper, that program was part of United States' effort to project America as a world power.⁹ For that purpose, the new embassies should be evidence of American goodwill and commitment to the new world era, and its modern architecture "introduced in the late 1940s, has come to symbolize the openness of public diplomacy" (Loeffler 2011, 3). In other words, these new buildings should express prosperity, technical innovation, generosity, and goodwill—in this case, through open and accessible spaces. The monumentality that Thomas Hines opposed (such as in the Karachi embassy, as in all embassies of the period) was not just the architects' will, but a requirement from the Office of Foreign Building Operations.

The second aspect is related to the final design that Hines, once again, based primarily on Robert Alexander's testimony to justify why certain aesthetic decisions were strange to him. An isolated analysis of this building, without considering Neutra's professional trajectory and works, could even lead one to understand that Hines is, in fact, correct in his assessment. However, the purpose here is to clarify that this design is not an unfortunate result of the partners' disagreement. Much to the contrary, it demonstrates the method of a mature architect that studied and understood the solutions of his fellow colleagues, in this case from Latin America. He was able to adapt their solutions to the specific conditions of the regions in which he worked.

Regardless of who found the vault molds, Neutra was responsible for the architectural decisions, and used this opportunity to experiment with an aesthetic that was new for him. His relations with Brazilian architects were essential in this matter. According to Roberto Segre, reinforced concrete molded shapes, typical of Brazil and internationally known, were part of the national initiative to define the country's future parameters of modern construction (Segre 2009, 171).

From the beginning of his professional activity, [Oscar] Niemeyer assumed the reinforced concrete as the basic material for his architectural production. His enthusiasm based on cement's availability and low cost in Brazil, and on construction creative tradition forged by local engineers that persistently defied the rigid European and North American structure norms. Their innovations allowed unseen technical solutions. The goal was to explore the possibilities of this new material by reducing the system pillar-beam, commonly used in wood and steel structures. But, as demonstrated by 1920s German expressionist architects—at Rudolf Steiner's Goetheum—the material plasticity motivated the exploration of new ways. And, at the same time, with the use of vaults and domes, it was possible to cover up spaces of wide dimensions. (Segre 2009, 169, author's translation)¹⁰

As in Brazil, Pakistan's industrialization and constructive possibilities did not allow the use of wood or steel structures, common for Neutra. So, the answer was the use of reinforced concrete, such as in the designs for Puerto Rico and for the Tremaine and Alfred De Schulthess houses. However, the concrete vaults for the embassy's warehouse were more than a simple response to the availability of the material. They allow extensive areas with very little support—ideal for such use—and give character to the design. In other words, they are more than "a meaningless series of equally bland vaults used to decorate the façade" (Hines 2005, 267). Just like the artistic panels of Los Angeles Hall of Records, they demonstrate the ability of a mature architect who studied with genuine attention his colleagues' designs and recognized aspects of their work that interested him.

CONCLUSION

To be modern is to find ourselves in an environment that promises us adventure, power, joy, growth, transformation of ourselves and the world and, at the same time, that threatens to destroy everything we have, everything we know, everything we are. (Berman 1988, 15)

In his essay on society and culture of the nineteenth and twentieth centuries, Marshall Berman says that being modern is to be in a constant search for growth, self-transformation, and transformation of the world around us. Richard Neutra is a testimony of that. In his many trips, publications, and connections established around the world, he clearly expressed his belief in transforming others and himself. He constantly sought to incorporate in his architecture technological innovations, his appreciation for landscape, art, and even his restlessness to the challenges afforded by climate and local conditions. Also, he never hid his admiration for the work of his colleagues—regardless of where they were from—nor his desire to always keep in touch with them. The immense archive of letters held by UCLA and the various books and articles written and published in many different countries are proof of that.

Even so, the historiographical discourse insists on denying the transformative process that Neutra underwent throughout his professional life, especially in relation to Latin America. The 1945 trip through South America is not described with the same enthusiasm as the 1930 tour to Europe and Asia, perhaps because the first was financed by the United States government, or maybe because the Bauhaus is more significant to historians than Latin America. Regardless of the motives, the fact is that current discussions on the architect's trajectory constantly repeat Thomas Hines and Barbara Lamprecht's assessments, without given them any critical review; even Latin American researchers are guilty on this score.

Latin American architecture in general is being repositioned by important researchers who dare to discuss history through different points of view. However, in the specific case of Richard Neutra, this process is still weak and lacking effort. Therefore, assuming the role of the noisy researcher—a character created by Ruth Verde Zein in her tale about the documentation of architecture historiography (Zein 2019, 102-125)—the Ph.D. research at the origin of this paper throws itself into the difficult task of bringing a new interpretation of Richard Neutra's work, one that originates from Latin America.

The focus on the existing historiography on Neutra means more than a simple design analysis—even though it is never simple. The designs are, in fact, motivation for studying the impact of Latin American architecture on Neutra's works. The reverse is easier to identify: as revealed in just a few glances at the

numerous publications of his designs in Latin American magazines; the books published in Portuguese and in Spanish; and the testimony of many Latin American architects. How can one understand the inverse if the existent discourse always denies it?

Starting from apparently insignificant identifications, it is possible to highlight an unknown aspect of Richard Neutra. His intense relation with Latin American architects, landscape designers and intellectuals had an actual impact on his designs after 1945, and not only during the period he designed the hospitals, schools and health centers for Puerto Rico—as the historiographical discourse insists on stressing—, but because he encountered in Latin America interlocutors that shared his desire to explore climate and local constructive conditions. Even more importantly, they shared the architectonic solutions that he constantly sought.

ENDNOTES

1 Original Portuguese book excerpt: "Os problemas históricos são resolvidos por meio da pesquisa. Exerce-se a operação crítica para garantir a exatidão dos dados e sua pertinência. Trata-se de problemas de ordem técnica. Os problemas historiográficos, pelo contrário, estão comprometidos diretamente com a ideologia do historiador, pois realizam o recorte de seu objeto de estudo e de seus instrumentos críticos, para a definição da estrutura do texto historiográfico; tudo aquilo, enfim, que o levará à interpretação do significado dos fatos e, por fim, à formulação de sua própria versão do tema escolhido."

2 As it is known, the Grande River's headspring is located at South of Colorado and it has its river mouth near the Gulf of Mexico. In its route, Grande River defines almost the entire U.S.-Mexican border.

3 All this information was collected in local newspapers and on the *Neutra Collection* archive held by UCLA. In the author's master thesis, this trip was carefully described (Critelli 2015).

4 Raymond Richard Neutra, in discussion with the author, July 2014.

5 Although the English version available uses the term "uncanny" as a translation of "unheimlich", for the purpose of this paper it was opted to use the Spanish translation, "lo siniestro," that seemed more appropriate.

6 Both on Alexander's memories held at the archives of Cornell University (Alexander, Robert E. "Unpublished memoirs." Alexander Papers, Cornell University) and on Hines interview with Alexander, December 1978 (Hines 2005).

7 Both at the Museum of Modern Art – MoMA at New York: "Portinari of Brazil," October 9 to November 17, 1940; and "Twenty Centuries of Mexican Art," May 15 to September 30, 1940.

8 Original Portuguese book excerpt: "a expressão *brasileira* da herança do racionalismo europeu [...] é a presença dos painéis cromáticos ou figurativos nos muros dos embasamentos dos edifícios: eles aparecem nos azulejos de Cândido Portinari no MES; o uma persistente colaboração do Athos Bulcão nos projetos realizados no início da construção da capital: por exemplo, no Brasília Palace Hotel (1957)."

9 The term "project America" is a direct reference to Justin Hart's book *Empire of Ideas: The Origins of Public Diplomacy and the Transformation of U.S. Foreign Policy* (Hart 2013).

10 Original Portuguese book excerpt: "Desde o começo da sua atividade profissional, Niemeyer assumiu o concreto armado como o material básico da sua produção arquitetônica. O seu entusiasmo se baseava na disponibilidade e o baixo custo do cimento no Brasil, e na criativa tradição construtiva forjada pelos engenheiros locais, que persistentemente questionaram as rígidas normas estruturais provenientes da Europa e dos Estados Unidos, e cujas inovações permitiriam soluções técnicas inéditas. O objetivo era explorar as possibilidades construtivas do novo material que se iniciou reproduzindo o sistema trilitico de coluna e viga, utilizado nas estruturas de madeira e de aço. Mas como bem demonstraram os arquitetos expressionistas alemães nos anos vinte—no Goethe-anum de Rudolf Steiner—, a plasticidade do material motivava explorar novos caminhos formais. E ao mesmo tempo, com o uso de arcos e abóbadas, era possível cobrir espaços de grandes dimensões".

REFERENCES

- Atique, F. 2010. Arquitetando a "Boa Vizinhança." *Arquitetura, Cidade e Cultura nas Relações Brasil-Estados Unidos 1876-1945*. São Paulo: Pontes.
- Bandeira, L. A. M. 1973. *Presença dos Estados Unidos no Brasil*. Rio de Janeiro: Civilização Brasileira.
- Baxandall, M. 1985. *Patterns of Intention: On the Historical Explanation of Pictures*. New Haven, London: Yale University Press.
- Berman, M. 1988. *All that is Solid Melts into Air*. Harmondsworth: Penguin Books.
- Bloom, H. 1997. *The Anxiety of Influence: A Theory of Poetry*. New York: Oxford University Press.
- Blumenthal, M. D. 1968. "The Economic Good Neighbor Aspects of United States Economic Policy Toward Latin America in the Early 1940s As Revealed by the Activities of the Office of Inter-American Affairs." PhD diss., Wisconsin: University of Wisconsin.
- Boesiger, W. 1951. *Buildings and Projects: Richard Neutra, 1927-1950*. Zurich: Girsberger.
- Boesiger, W. 1959. *Buildings and Projects: Richard Neutra, 1950-1960*. Zurich: Girsberger.
- Boesiger, W. 1969. *Buildings and Projects: Richard Neutra, 1961-1966*. Zurich: Girsberger.
- Castillo, J. V. 2003. *Richard Neutra: Un Lugar para el Orden. Un Estudio Sobre la Arquitectura Natural*. Sevilla: Editora Universidad de Sevilla, Consejería de Obras Públicas y Transportes.
- Cavalcanti, L. 2006. *Moderno e Brasileiro: A História de uma nova Linguagem na Arquitetura (1930-60)*. Rio de Janeiro: Jorge Zahar.
- Cramer, G., Prutsch, U. 2012. *¡Américas Unidas! Nelson A. Rockefeller's Office of Inter-American Affairs (1940-46)*. Madrid/Frankfurt: Iberoamericana/Vervuert.
- Critelli, F. 2015. "Richard Neutra e o Brasil." Master thesis, São Paulo: FAU-Mackenzie.
- Cronan, T. 2011. "Danger in the Smallest Dose: Richard Neutra's Design Theory." *Design and Culture*, 3 (2): 165-192.
- Del Real, P. 2012. "Building a Continent: The Idea of Latin American Architecture in the Early Postwar." PhD diss., New York: Columbia University.
- Ettinger, C. R. 2018. *Richard Neutra en América Latina: Una Mirada Desde el Sur*. Guadalajara: Arquetônica.
- Freud, S. 1919. "Lo Siniestro," in: *Sigmund Freud – Obras Completas*. 2017. Madrid: Biblioteca Nuova.
- Freud, S. 1919. "The Uncanny." Available in: <https://web.mit.edu/allanmc/www/freud1.pdf>.
- Ginzburg, C. 1993. "Microhistory: Two or Three Things That I Know About It." *Critical Inquiry* 20 (March-June): 10-35.
- Glinkin, A. 1990. *Inter-American Relations: From Bolívar to the Present*. Moscow: Progress Publishers.
- Guerra, A., and Fernanda Critelli. 2013. "Richard Neutra e o Brasil." *Arquitextos* 14, no. 159.00, <http://www.vitruvius.com.br/revistas/read/arquitextos/14.159/4837>.
- Hart, J. 2013. *Empire of Ideas. The origins of Public Diplomacy and the Transformation of U.S. Foreign Policy*. New York: Oxford University Press [e-book].
- Hines, T. S. 2005. *Richard Neutra and the Search for Modern Architecture*. New York: Rizzoli.
- Hines, T. S., DREXLER, A. 1982. *The Architecture of Richard Neutra: From International Style to California Modern*. New York: The Museum of Modern Art.
- Lamprecht, B. M. 2010. *Richard Neutra: Complete Works*. Colonia: Taschen.
- Lamprecht, B. M. 2012. "The Obsolescence of Optimism? Neutra and Alexander's U.S. Embassy, Karachi, Pakistan." Available in: <https://barbaralamprecht.com/2012/06/23/the-obsolescence-of-optimism-neutra-and-alexanders-u-s-embassy-karachi-pakistan/>
- Lavin, S. 2004. *Form Follows Libido: Architecture and Richard Neutra in a Psychoanalytic Culture*. Cambridge: MIT Press.
- Leatherbarrow, D. 2002. *Uncommon Ground: Architecture, Technology, and Topography*. Cambridge: MIT Press.
- Leonard, T. 1999. *United States-Latin American Relations, 1850-1903*. Tuscaloosa, London: The University of Alabama Press.
- "Letter from Charles W. Collier to Richard Neutra," September 14, 1945. Folder 8. Box 1429. Office Records, Correspondence. Neutra Collection. UCLA Library of Special Collections.
- Liernur, J. F. 1998. "Latin America: The Places of the 'Other.'" In *At the End of the Century: One Hundred Years of Architecture*, edited by R. Koshalek, E.A.T. Smith, and C. Zeynep, 276-320. New York: Abrams.
- Liernur, J. F. 2010. "The South American Way". O Milagre Brasileiro, os Estados Unidos e a Segunda Guerra Mundial – 1939-1943." In *Textos Fundamentais Sobre História da Arquitetura Moderna Brasileira – Parte 2*, edited by A. Guerra, 169-217. São Paulo: Romano Guerra.
- Loeffler, J. C. 2011. *The Architecture of Diplomacy: Building America's Embassies*. New York: Princeton Architectural Press.
- Lübken, U. 2012. "Playing the Cultural Game: The United States and the Nazi Threat to Latin America," in *¡Américas Unidas! Nelson A. Rockefeller's Office of Inter-American Affairs (1940-46)*, edited by G. Cramer, U. Prutsch, 53-76. Madrid/Frankfurt: Iberoamericana/Vervuert.

- Minchillo, C. Cortez. 2015. *Erico Verissimo, Escritor do Mundo: Circulação Literária, Cosmopolitismo e Relações Interamericanas*. São Paulo: EDUSP.
- Moura, G. 1984. *Tio Sam Chega ao Brasil: A Penetração Cultural Americana*. São Paulo: Brasiliense.
- Moura, G. 2013. *Brazilian Foreign Relations 1939-1950: The Changing Nature of Brazil-United States Relations During and After the Second World War*. Brasília: Fundação Alexandre Gusmão.
- Neutra, R. J. 1937. "Arquitetura Funcional." *Revista de Engenharia Mackenzie* 67 (October): 132-3.
- Neutra, R. J. 1946a. "Observations on Latin America." *Progressive Architecture* 5 (May): 67-72.
- Neutra, R. J. 1946b. "Sun Control Devices." *Progressive Architecture* 10 (October): 88-91.
- Neutra, R. J. 1948. *Arquitetura Social em Países de Clima Quente/Architecture of Social Concern in Regions of Mild Climate*. São Paulo: Todtmann.
- Neutra, R. J. 1950. "Uma Casa Inédita de Neutra." *Pilotis* 4 (February): 4-9.
- Neutra, R. J. 1954. *Survival Through Design*. New York, Oxford University Press.
- Neutra, R. J. 1957. *Planificar para Sobrevivir*. Mexico, Buenos Aires: Fondo de Cultura Económica.
- Neutra, R. J. 1958. *Realismo Biológico: Um Nuevo Renacimiento Humanístico en Arquitectura*. Buenos Aires: Nueva Visión.
- Neutra, R. J. 1959a. "Dos Aspectos Formais Não Visuais do Plano da Cidade e seu Contexto Urbanístico." *Habitat* 57 (November): 16-17.
- Neutra, R. J. 1959b. "Planejamento: um Problema Humano, com Base no Indivíduo." *Módulo* 15: 14-17.
- Neutra, R. J. 1962a. *El Mundo y la Vivienda*. Barcelona: Gustavo Gili.
- Neutra, R. J. 1962b. *Life and Shape*. New York: Appleton Century Crofts.
- Neutra, R. J. 1972. *Vida y Forma*. Buenos Aires: Marymar.
- Radford, A., Selen Morkoç, and Amit Srivastava. 2014. *The Elements of Modern Architecture: Understanding Contemporary Buildings*. London: Thames and Hudson.
- "Report on visit South American Republics, by Richard Neutra, architect and President, U.S. Chapter of Congres Internationeaux d'Architecture Moderne," 1946. Folder 8. Box 1429. Office Records, Correspondence. Neutra Collection. UCLA Library of Special Collections.
- Robin, R. 1992. *Enclaves of America: The Rhetoric of American Political Architecture Abroad, 1900-1965*. New Jersey: Princeton University Press.
- Said, E. W. 1994. *Culture and Imperialism*. New York: Vintage Books.
- Segre, R. 2009. "Oscar Niemeyer: Tipologias e Liberdade Plástica," in *Tributo a Niemeyer*, edited by A. Petrini, 163-175. Rio de Janeiro: Viana&Mosley.
- Stevens, G. 2003. *O Círculo Privilegiado: Fundamentos Sociais da Distinção Arquitetônica*. Brasília: Editora UnB.
- Tota, A. P. 2000. *O Imperialismo Sedutor: A Americanização do Brasil na Época da Segunda Guerra*. São Paulo: Companhia das Letras.
- Tota, A. P. 2014. *O Amigo Americano: Nelson Rockefeller e o Brasil*. São Paulo: Companhia das Letras.
- Vleck, J. V. 2013. *Empire of the Air: Aviation and the American Ascendancy*. Cambridge: Harvard University Press. E-book.
- Waisman, M. 2013. *O Interior da História: Historiografia Arquitetônica para Uso de Latino-Americanos*. São Paulo: Perspectiva.
- Zein, R. V. 2019. *Critical Readings*. São Paulo; Austin: Romano Guerra; Nhamerica Platform.

POSTCOLONIAL POSSIBILITIES OF ARCHITECTURAL HISTORY: Questions and Concerns in reading the Urbanisms of the Global South

Soumya Dasgupta
University of Illinois at Urbana-Champaign

Abstract: As the twenty-first century unfolds before us, the megacities of Global South experience unprecedented urbanization characterized by informalizations of urban spaces. While several new theoretical perspectives from fields such as geography, sociology, and urban planning are contributing heavily in understanding and explaining these mega-urbanisms of the Global South and their complicated and contested narratives, Architectural History, as a discipline, still struggles to articulate these transformations meaningfully. In the context of this epistemological dichotomy, this paper delves into an academic multilogue between architectural history as a methodological apparatus to read and understand space, recent theoretical insights from related built-environment disciplines that reflect on the Global South, and critical theories that help us understand socio-spatial processes, productions, and practices. In doing so, this paper first critiques the role of architectural history in its inability to include much of the spatial narratives of the Global South and questions the canonical understandings of architecture that most of its present academic pedagogy perpetuates. Second, it discusses the potentials of how and what architectural history and theory can learn from contemporary discourses in neighboring subjects. Third, it calls for a postcolonial intervention into architectural history and theory to enunciate the spatial narratives of the understudied Global South. Further, by configuring a critical conversation between theoretical perspectives such as Bhabha's 'hybridity', Lefebvre's triad of spatial productions, Certeau's 'strategies and tactics,' Bayat's 'quiet encroachment,' and Harvey's 'insurgent architect' this paper proposes an analytical framework that might help us read the complex, entangled, and contested urbanisms of the Global South and the history of their architectural productions.

Keywords: Architectural history, postcolonial studies, Global South

INTRODUCTION

There has been a long-standing epistemological dichotomy in architectural studies, which is of serious concern to various scholars of the Global South today. While on the one hand, architectural history fails to accommodate the spatial narratives of unprecedented massive urbanization processes in twenty-first century megacities, on the other hand, postcolonial studies hardly capture the architectural movements of these societies. This investigation picks up on this juncture and critically analyzes this gap. Building on this, it further speculates on the possible intersection between postcolonial theory and architectural history, and sheds light upon how such an intersection might give us new directions for understanding the questions and concerns that are necessary to read the urbanisms of Global South societies today.

This paper has three parts. First, by tracing various developments in architectural history and by referring to some key texts from the last century, I discuss why and how architectural history falls short in its scope to discuss spatial productions and practices in the context of the Global South, and highlight why such a limitation is of concern. Second, I refer to emergent research in

associated built environment disciplines that reveal similarities with architectural inquiries to trace how they have studied the "megacity" in Global South, in order to shed light on possible crossroads. Finally, in the third part, I use several examples of critical scholarship from postcolonial and poststructural theories and propose an analytical framework that may lead to a possible postcolonial intervention in architectural history.

1. LIMITATIONS OF ARCHITECTURAL HISTORY

Architectural history, hitherto primarily produced in Europe and America, has not been able to talk much about societies of the Global South. Western historians who have written about the non-West have, by the very weight of the category, studied it through, what Said has discussed as an orientalist lens (Bozdogan 1999; Akcan 2016). In particular, for the period from the mid-nineteenth to mid-twentieth century, not only do we not have architectural accounts of the different histories that shaped the postcolonial Global South, but we also do not have scholarship that reflects upon the sense of 'architecture' that emerges from and represents the built environment and spatial practices of these geographies.

Furthermore, since the mid-nineteenth century, architectural history as a discourse has been politically dominated by the “architect’s history,” which necessitates the existence of an institutionalized architect, culturally recognized by the West (Bozdogan 1999; Coldstream 2003). These politics have manifestations that not only marginalize all other modes of thinking about what architectural history is, but also have far-reaching impacts that shrouded any other discourse of who is considered an architect, especially in the complicated and contested geopolitical contexts of the developing world.

Nevertheless, in the latter half of the twentieth century, two new directions have emerged from the West to look at the underexplored developing world and its’ lesser-known architects. First, the development of vernacular architecture as a new epistemology looks back at “pre-modern” forms of traditional dwellings and non-pedigreed architects (Rudofsky 1965; Rapoport 1975) chiefly through climatic and cultural lenses, and argued in favor of their indigeneity and sustainability. Second, the development of critical regionalism focused on the indirect derivation of particularities of a region as a mediating strategy to resist the homogenizing forces of universalization (Frampton 1983; Lefavre and Tzonis 2003), such as the architectural works of Charles Correa, Geoffrey Bawa, B.V. Doshi, Raj Rewal in the South Asian geopolitical context. While these two radical changes in perspectives do encourage us to see forms, spaces, and narratives beyond the lens offered by traditional Western architectural scholars, I argue that, because of a lack of Postcolonial intervention, they fall short of capturing the contestations and negotiations of the massive urbanizations of the Global South. Under three broad themes, I discuss why architectural history at its present moment is underprepared to take up this task.

1.1. OTHER

Much like history, architectural history, burgeoned within the colonial and imperial enterprises of Europe and America, and, has been shackled by a perspective that Said in 1978 described as Orientalism (Said, Bayoumi, and Rubin 2019). Said uses Foucault’s reflections on authoritarian power and knowledge, along with Gramsci’s discussion on hegemony, to explain how the purpose of knowing the ‘orient’ through the colonizer’s gaze, necessitated a willful misrepresentation of it to gain and maintain control over it. Although much less acknowledged, architectural history has not only been dominated by this orientalist perspective but also aided in constructing this very perspective, which operates for and from a positionality that is West-centered. It is important to emphasize here that this gaze, not only influenced the production of architectural histories of

the colonial peripheries, but that such tendencies could also be traced back to texts produced within the center.

For example, let us critically consider the famous lectures on architecture by Viollet-Le-Duc, which had substantial influence in shaping the understanding of what defines architecture for generations to come (Viollet-Le-Duc 1877). His introductory struggle to separate the high arts from the “barbarous” is quite telling of the inherent tensions that were latent, as the cultures around him are gradually exposed to external influences. Following the traditions of the *Ecole-de-Polytechnique* school of thought in France, Le-Duc confines his texts within four categories of arts (Music, Architecture, Sculpture, and Painting) and repeatedly emphasizes the necessity of a “civilized man” to understand and appreciate arts as an instinctual response to the craving of the mind. Why is Viollet-le-Duc so concerned with the “civilized man”? What, according to him, is the “barbarous”? Moreover, how does art help make a distinction between the two? In his very normative tone present in many contemporaneous texts, Viollet-le-Duc assumes his position of superiority and dictates in a rather direct and legible way, “Building a hut with branches of trees is not Art; it is merely the supplying of a material want” (Viollet-le-Duc 1877, 12).

While it is important to note here that Viollet-le-Duc indeed fails to see art in the building of a hut with tree branches, what is even more interesting and significant is that in his struggle to define what art is, he cannot define it in its own terms, and gets conditioned by its other, i.e., what art is not (e.g., art is not “barbarous”). This underlying effort to appraise art and proclaim the superiority of the artist distinctly marks his text, while it also delineates a boundary beyond which lies every other “other” of art. Furthermore, while it can be argued whether such effort to define and confine the realm of art and its mastery is at all relevant or agreeable, it is striking, if not shocking, to note how such preferential treatment of art, provides Viollet-le-Duc a standpoint from which to politicize its different reception, in order to delegitimize the orient. For example, in discussing the interrelation of God, imagination, sculpture, and the “savage,” he writes, “If the savage be a Hindoo or an Egyptian, he will soon aspire to make his god in material form such as his imagination depicts him” (Viollet-Le-Duc 1877, 23).

While such statements are highly problematic, and perhaps unacceptable to most today, it is crucial to understand the underlying project of how such thought processes that create a boundary around artistic productions continue to perpetuate in our thinking today.

A detailed critique of Viollet-le-Duc’s lectures is indeed not the primary objective of this paper. However, I have tried to show how, in creating such a space of

the other in order to establish an absolute superiority, the perspective inherently limits itself in knowing about these othered conditions. While such tendencies are perhaps most prominent in this particular text, they are not exclusive to it and can be observed throughout what becomes identified as the Western canon, such as in the texts of Ruskin, Semper, Wolfliin, Scott, and Panofsky.

Nevertheless, how does this conditioning of the other aid or harm the production of knowledge about the non-West? Is it by fundamentally knowing the orient as other, that the canon loses its ability to introspect meaningfully into the non-West? How does acknowledging the colonial gaze restrict what the Western canon can explore? These questions get further complicated by yet another aspect of the methodological apparatus that is prevalent throughout architectural history, the distanced gaze.

1.2. VIEWING

In his text *The Shape of Time* (Kubler 1962), Kubler provides a perspective that was radically fresh in its time. For Kubler, the historian is tasked with the portrayal of a time, in a configuration resembling an astronomer observing the stars (Kubler 1962, 19). The historian ends up knowing and portraying time, as much as the astronomer ends up knowing about the stars. The stoicism inherent in this methodology is crucial here, as the historian places *himself*¹ distanced from time, *his* ability to portray time is as limited as that of astronomers' ability to portray stars. While Kubler emphasizes the need for this distance throughout his text to prioritize the reading of signals from historical objects, he never really explains its necessity, and rather assumes this positionality for the historian. Such a positionality of the historian distanced from the time, apparently justifies problematic correlations such as "Craft education is the activity of groups of learners performing identical actions, but artistic invention requires the solitary efforts of individual persons" (Kubler 1962, 15).

How then does the historian reach such conclusions if indeed *he* is distanced from the time to be portrayed? Such distance, I argue, privileges individuality over collective endeavors and thus exposes the problematics of the author's normative position about craft and art. Kubler fails to see the essence of invention in group work, flattens craft education as "identical actions," and fails to explain why the activity of groups producing craft is different from a solitary individual producing art. Again, we find texts that represent the canon, using their strategic historicism to create distance from the subject.

Such a distanced gaze faces substantive criticisms in the post structural reflections on everyday life

that emerged a few decades later in Certeau's work (Certeau, 1984), which discusses the limitations of its scope even further. Certeau clearly states that the widespread circulation of images and narratives that are perpetuated in our societies hardly let us know anything about how the consumer uses a product. He encourages us to look for alternative approaches grounded on the street level, rather than the all-encompassing Icarian viewpoint. He says:

To be lifted to the summit of the World Trade Center is to be lifted out of the city's grasp...An Icarus flying above these waters, he can ignore the devices of Daedalus in mobile and endless labyrinths far below. His elevation transfigures him into a voyeur. It puts him at a distance. It transforms the bewitching world by which one was "possessed" into a text that lies before one's eyes. It allows one to read it, to be a solar Eye, looking down like a god. The exaltation of a scopic and gnostic drive: the fiction of knowledge is related to this lust to be a viewpoint and nothing more. (Certeau 1984, 92)

The architect's obsession with the bird's eye view, in imagining *his* grand design, in being the voyeur of a future resembles the air-view that is employed by the architectural historian to create the fiction of the city's history (Summerson 1969). City, then in this voyeuristic gaze, becomes a fictional knowledge for many architectural historians (such as Summerson, Kostoff, and Mumford) who begin by putting themselves, much like Kubler recommends, at a distanced, elevated position of power and, in possession of specific expertise in the text, producing the criteria of determination. While I by no means question the credibility of the knowledge produced by these authors, I do wish to point out the inherent limitations for history-writing that is associated with assuming a positionality from where it is convincingly determined.

1.3. INSTITUTIONALIZATION

Who is considered an architect? Who determines this? Moreover, what role does architectural history play in the making of the architect? Such inquiries that question the normativity of discourse were perhaps not prominent before the postmodern turn in the middle of the last century, when authors and activists from various backgrounds were fighting the hubris of the modern heteronormative white male architect. Some sharply questioned the self-fancied position of power that allowed architects to foster a nostalgia of the future (Moholy-Nagy 1961), some emphasized the need to engage in complexities and contradictions in architectural thinking (Venturi 1977), some reflected deeply on the politics of bricolage (Rowe and Koetter 1975), and some launched a full-fledged attack on the institutionalized, state-sponsored practice of city planning (Jacobs 1961).

However, it was perhaps not until the groundbreaking exhibition entitled "Architecture without Architects" at the Museum of Modern Art in New York that a possible alternative to the licensed architectural practices was found (Rudofsky 1965). While the title of this exhibition and book was quite radical in its context, and it captured architectural forms and spaces from *vernacular* cultures, it is also interesting to note that it created a theoretical category of "non-architects." Thus, while many argue that the epistemological category of "vernacular architecture" does enable us to study and analyze built environments supposedly outside the canon, it again reinforces the institutional pedagogy to define and control them as separate. Similarly, in Rapoport's work (Rapoport 1975), categories such as "vernacular architecture," "shelter," "folk architecture," while studied extensively, are somehow put in a pre-modern and non-urban space, and the agency of their producers becomes other to that of the work of licensed, institutionalized architects.

These limitations, identified in three categories, expose the inherent vulnerabilities of architectural studies in understanding and reading built environments, forms, and spaces within the established and relatively stable Western canon. For the Global South then, where the megacity provides conditions that are even more complicated, contradicted, and contested, how can we rely on architectural history and its methodological apparatus? What can we learn from the built-environment disciplines, such as urban planning, sociology, or geography?

2. URBAN INFORMALITY

Rooted in the economic concept of the informal sector (Hart 1973) urban informality has become a subject of scholarly interest across disciplines such as urban planning, sociology, and geography. Within the context of the Postcolonial Global South, urban informality has nuanced understandings of employment, citizenship, poverty, and urban space. It has been used to explain a range of socio-spatial, socio-economic, and socio-political aspects of megacities such as slums, pavement-dwelling, street-hawking, urban poverty, subaltern social movements, non-movements, everyday resistance, and "illegal" encroachments to name a few. Urban informality and related concepts, such as quiet encroachment (Bayat 2000), occupancy urbanism (Benjamin 2008), insurgent planning (Miraftab 2016), messy urbanism (Hou and Chalana 2017), broadly capture the research area that discusses what is fundamentally different between the canonical epistemes of "cities" and the cities of the Global South and how such differences manifest in their corresponding built environments and spatial practices.

Important to emphasize here, is how far away from their disciplinary canons these researches go, in order to be able to capture in bits the contested landscapes of the contemporary Global South megacities. Some scholarship has not only gone beyond the prevalent theoretical paradigm, but has also challenged the very disciplinary dogmas they emerge from. This is partly because of the inherent limitations of the canonical apparatus of the disciplines themselves, and partly due to the new effort in articulating the underexplored Global South, which the canon fails to do theoretically. Roy has captured this epistemological crisis in a rather straightforward way as "the dominant theorizations of global city-regions are rooted in the EuroAmerican experience and are thus unable to analyze multiple forms of metropolitan modernities" (Roy 2009, 819).

However, we cannot operate under the assumption that the larger body of Postcolonial criticisms have been fruitful in dismantling architectural history's eurocentrism, as much as it has done so in other disciplines. As recent intellectual endeavors of rethinking the canon have revealed:

Art and architectural history have responded to Said's challenge, albeit on a more subdued scale than some other academic fields. Not surprisingly, much of this recent scholarship follows the model established by Orientalism and engages in a series of analyses focusing on works of art and architecture that contribute to the construction of an "Orient." (Camille et al. 1996, 202)

Most architectural historians who have worked in the context of the 21st century megacity in the Global South have either relied on other fields, looked at the Global South through a mixed lens approach, or have used their architectural expertise to investigate the urban fabric, while avoiding the question of "architecture" altogether. A strong questioning of the field of architectural history and how it shapes the meaning of 'architecture' is yet to come forth. While a crisis was felt for a long time in the discourse, it was perhaps not until Esra Ackan's text entitled "Postcolonial Theories in Architecture" that these possible interventions made themselves heard. Ackan, referring to Bozdogan's work, says, "Apart from suggesting an emphasis on intertwined histories, Bozdogan argues . . . that only when a non-Western architect "reaches the level" of Western "skill and sophistication," can s/he be appreciated and press the boundaries of the canon" (Ackan 2016, 136).

How can we further Ackan's discussions on postcolonial theories *in* architecture, of what can be a postcolonial theory *of* architecture? How can it have a critical conversation with postcolonial urban theory (Roy 2016)? And then, how does architectural history reflect on the postcolonial space? These are the theoretical investigations that guide the locus of my work and

situates it in the intersection of architectural history and urban informality.

3. PROPOSED FRAMEWORK

For my doctoral work, I am attempting to write an architectural history of urban informality that can help explain the entangled spatial productions of Global South megacities from an architectural perspective. For this, I have found the proposition of insurgent architects (Harvey 2000) as a useful category. Insurgent architects, as Harvey explains, are embodied beings, who do not have institutionalized training or licenses, but by their practice, they subvert the dominant spatial order. I argue that investigating the various design tactics employed by insurgent architects in producing such forms and spaces will give us deeper insight into the making of urban informality, not only as a “new” way of life (AlSayyad 2004) but also as a mode of spatial production (Lefebvre 1991).

3.1. POSTCOLONIAL HYBRIDITY

In his essay “Signs taken for Wonders,” Homi K. Bhabha introduces the concept of hybridity in the context of postcolonial cultural productions (Bhabha 1985) which also appears in his book *The Location of Culture*, along with some more related discussions on concepts such as mimicry, sly civility, and most importantly the realm of ‘beyond’ (Bhabha 1994). For postcolonial, societal contexts, one should refrain from reducing the hybrid to a condition of either mixed/combined/overlapped/juxtaposed/multilayered/palimpsest, as some streams of architectural and urban design thinking that prioritize geometric forms and cartographic morphologies might tend to do. Instead, hybridity allows us to find meaning in the realm of in-between, combats polarization and rigid categories, and provides a way of thinking.

Bhabha roots his argument by emphasizing the ambivalence at the source of the colonial discourse of power, meaning that we need to question the overarching narrative that colonization of different geographies intended to reproduce and resemble the colonial centers. Instead, Bhabha finds a paradox that is: within the project of colonization, colonizers designed a partial influence for maintaining colonial dependency which simultaneously, for Bhabha, became the subversive grounds of insurgent interventions. It is in this milieu of cultural production that Bhabha, explaining hybridity, writes:

If the effect of colonial power is seen to be the *production* of hybridization rather than the noisy command of colonialist authority or the silent repression of native traditions, then an important change of perspective occurs. It reveals the ambivalence at the source of traditional discourses on authority and enables a form

of subversion, founded on that uncertainty, that turns the discursive conditions of dominance into grounds of intervention. (Bhabha 1985, 154)

Taking up Bhabha's challenge in writing a history of architecture requires distancing ourselves from our dispositions with specificity and coming to terms with unknowing, and understanding that the unknowable, in fact, is part of the knowable.

3.2. HYBRID SPATIAL PRODUCTIONS

Lefebvre, in his highly regarded book, *The Production of Space*, proposed a triad for analyzing spatial productions, following a Marxist approach that society secretes its own space, or even more obviously, (social) space is a (social) product (Lefebvre 1991). The triad suggested that space is produced by a dynamic interrelation of the following analytic categories: spatial practice, representations of space, and representational space. Accordingly, spatial practice embodies “a close association, within perceived space, between daily reality (daily routine) and urban reality (the routes and networks which link up the places set aside for work, ‘private’ life and leisure)”; representations of space are “conceptualized space, the space of scientists, planners, urbanists, technocratic subdividers and social engineers, as of a certain type of artist with a scientific bent—all of whom identify what is lived and what is perceived with what is conceived”; and, representational space signifies “space as directly lived through its associated images and symbols, and hence the space of ‘inhabitants’ and ‘users’” (Lefebvre 1991, 38-39).

Now we can ask, is Lefebvre's triad robust enough to help us understand the ambivalent productions of hybrid spaces in twenty-first century postcolonial societies? Consider the case if we were to take Lefebvre's triad to the slums of Mumbai or the favelas of Rio de Janeiro and try to make sense of them. Indeed, the slums and favelas are built and lived environments. One can understand their spatial practices, albeit to a limited extent, through observing their gradual transformation over time via satellite imagery, by surveilling them through different state apparatuses, such as police or planning agencies, or by the ethnographic projects by academic researchers who engage with the community and document anecdotal accounts. Furthermore, if one chooses to represent these understandings, by doing an art project, writing a research paper, making a documentary, or producing full-fledged commercial films such as *Slumdog Millionaire* or *Gullyboy*, such spaces can then fit into what Lefebvre calls representational spaces.

The question that puts to the test the robustness of Lefebvre's triad, and thus also becomes the motivation of my project, concerns the representations of space

in the context of postcolonial hybridities? How can we make sense of the question—what is the conceptualized space of the slums or favelas, of barrios, of hawking, encroaching or poaching? Who are their conceptualizers?

3.3. STRATEGIES, TACTICS, QUIET ENCROACHMENTS, AND INSURGENT ARCHITECTS

Certeau's discussions regarding the consumption of culture and the role of the user in this process of consumption revolve around a deep discussion on the everyday life of the ordinary man (Certeau 1984). Certeau argues that to set up an understanding of cultural production, one must consider the everyday utilization of the products by the user. Certeau puts forth two concepts that are very crucial for this framework and this project, strategies and tactics, which originates in military lexicons to explain the utilization of time and space. In Certeau's words, "... strategies pin their hopes on the resistance that the *establishment of a place* offers to the erosion of time; tactics on a clever *utilization of time*, of the opportunities it presents and also of the play that it introduces into the foundations of power,' etc." (Certeau 1984, 38–39).

Strategies are organizations of spaces and units by broader frameworks of power or establishments, and tactics are manipulations of such organizations in the moment. Strategies and tactics within hybrid postcolonial spaces become a bit more complicated when the conditions are more contentious. How, for example, can we understand the street hawking in Calcutta? Despite the decade long strategic efforts of the State to remove hawkers, the street hawkers of Calcutta were successful in unionizing, resisting, and protecting their space in the city (Bandopadhyay 2016). Now, in a country like India, where most of the people belong to the informal sector, then it is not the case that, in terms of scale, the postcolonial context can potentially reverse the understanding of strategies and tactics, as Certeau described it?

Based on his observations on the Middle East over the last 20 years, Bayat argues that the absence of traditionally recognized cooperative or collective organizations amongst the urban poor does not necessarily suggest a paucity of grassroots activism; instead, the urban poor have resorted to, what Bayat refers to as an alternate strategy of quiet encroachment (Bayat 1996):

Quiet encroachment refers to noncollective but prolonged direct actions of dispersed individuals and families to acquire the basic necessities of their lives (land for shelter, urban collective consumption or urban services, informal work, business opportunities, and public space) in a quiet and unassuming illegal fashion. (Bayat 2009, 45)

This idea of quiet encroachment as a non-collective strategy of the urban poor to manipulate the imposing strategy (or lack thereof) of the State power and its spatial ordering is perhaps the most robust concept that explains the socio-economic and cultural dynamics of informal urban practices in Global South cities.

Quite related to this discussion is a similar perspective that gains mileage in David Harvey's relatively later work, in which he refers to the insurgent architect (Harvey 2000). In the chapter "The Insurgent Architect at Work" of the book *Spaces of Hope*, Harvey calls for the speculative future of praxis, where insurgent architects, who are embodied beings, are capable of altering the future locus of city-making, by intervening themselves into its means of productions. He says, "The insurgent architect, like everyone else, is an embodied person . . . The person is endowed with certain powers and skills that can be used to change the world" (Harvey 2000, 234).

Drawing from the multilogues under section three, I propose the following theoretical framework to analyze the architectural narratives of informalization processes in Global South megacities. First, to use Bhabha's postcolonial hybridity to look at the megacity. Second, to use Lefebvre's tripartite framework to understand its spatial productions. Third, advancing Certeau's idea of strategy and tactics to uncover the forms and spaces of informalities. Fourth, locating Harvey's idea of the insurgent architect, and Bayat's account of quiet encroachments respectively as producers and produced spaces of informalities.

4. CONCLUSIONS

Reading across literature from various disciplines, I have come to three interrelated concluding directions that can help mobilize the potentials of architectural history for engaging postcolonial urban space.

4.1. RETHINKING ARCHITECTURAL PEDAGOGY

Mainstream professional architecture courses continue to perpetuate an understanding of the history of modern architecture in terms of Le Corbusier, Frank Lloyd Wright, Bauhaus, and CIAM, and their postmodern criticisms are chiefly limited to the likes of Jane Jacobs, Robert Venturi, Collin Rowe, and Rem Koolhaas. The sheer suppression of the 'other' narratives, such as that of women or people of color or immigrants or indigenous societies or transnational standpoints, throughout the discourse spanning two centuries, is so potent that even to conceive of alternate historiographies that can meaningfully counter this canonical regime, presents an incredible intellectual, if not a political, challenge for the scholars of the twenty-first century. However, to bring forth such a radical change in architectural pedagogy,

architectural historians may find meaningful directions from the intersections of its neighboring disciplines with postcolonial studies.

4.2. ADDING ARCHITECTURAL NUANCES

Built environment disciplines such as sociology, urban planning, and geography are contributing heavily to studying the informalization processes of the urban Global South. However, these miss the architectural narratives of these spaces and their practices. This epistemological gap should be of concern, not only to architectural historians, but to all those who are studying spatial productions and practices in their geopolitical context. A postcolonial intervention is thus necessary, not only for the field of architectural history, but also for

all disciplines that architectural history can impact.

4.3. DEINSTITUTIONALIZING THE 'ARCHITECT'

A meaningful postcolonial intervention in architectural history is different from critiquing architectural history through a postcolonial lens. While the idea of the 'architect' has been questioned several times in different contexts, none have actually been able to penetrate the protective shield of institutionalization within which architects shelter themselves, both in the traditional sense and in the context of postcolonial societies. The category of the insurgent architect, as a possible venture to deinstitutionalize the role of architect in our societies may make way for a more meaningful role in architectural history's endeavor to narrate postcolonial urban space.

ENDNOTES

1 I use *himself/his/he* for the historian to correspond with the usage of this pronoun in the referred text.

REFERENCES

- Akcan, E. 2016. "Postcolonial Theories in Architecture." In *A Critical History of Contemporary Architecture*, edited by Elie G. Haddad and David Rifkind, 143–164. London: Routledge. doi: 10.4324/9781315263953-13.
- AlSayyad, N. 2004. "Urban Informality as a "New" Way of Life." In *Urban Informality: Transnational Perspectives from the Middle East, Latin America, and South Asia*, edited by Ananya Roy and Nezar AlSayyad, 7–30. Lanham: Lexington Books.
- Bandopadhyay, R. 2016. "Institutionalizing Informality: The Hawks' Question in Post-colonial Calcutta." *Modern Asian Studies* 50, no. 2 (March): 675–717. doi: 10.1017/S0026749X1400064X.
- Bayat, A. 1996. "Cairo's Poor: Dilemmas of Survival and Solidarity." *Middle East Report* 202 (Winter): 2–6, 12. doi: 10.2307/3013030.
- Bayat, A. 2000. "From "Dangerous Classes" to "Quiet Rebels": Politics of the Urban Subaltern in the Global South." *International Sociology* 15, no.3 (September): 533–557. doi: 10.1177/026858000015003005.
- Bayat, A. 2009. *Life as Politics: How Ordinary People Change the Middle East*, Second Edition. Palo Alto: Stanford University Press.
- Benjamin, S. 2008. "Occupancy Urbanism: Radicalizing Politics and Economy Beyond Policy and Programs." *International Journal of Urban and Regional Research* 32, no. 3 (September): 718–729. doi: 10.1111/j.1468-2427.2008.00809.x.
- Bhabha, H. K. 1985. "Signs Taken for Wonders: Questions of Ambivalence and Authority under a Tree outside Delhi, May 1817." *Critical Inquiry* 12, no. 1 (Autumn): 144–164. doi: 10.1086/448325.
- Bhabha, H. K. 1994. *The Location of Culture*. London; New York: Routledge.
- Bozdogan, S. 1999. "Architectural History in Professional Education: Reflections on Postcolonial Challenges to the Modern Survey." *Journal of Architectural Education* 52, no. 4 (May): 207–215. <https://www.jstor.org/stable/1425410>.
- Camille, Michael, Zeynep Çelik, John Onians, Adrian Rifkin, and Christopher B. Steiner. 1996. "Rethinking the Canon." *The Art Bulletin* 78, no. 2 (June): 198–217. <https://www.jstor.org/stable/3046172>.
- Coldstream, N. 2003. "The Architect, History, and Architectural History." *Transactions of the Royal Historical Society* 13 (December): 219–226. doi: 10.1017/S0080440103000112.
- De Certeau, M. 1984. *The Practice of Everyday Life*, first edition, translated by Steven Rendall. Berkeley; Los Angeles: University of California Press.
- Frampton, K. 1983. "Towards a Critical Regionalism: Six Points for an Architecture of Resistance." In *The Anti-Aesthetic: Essays on Postmodern Culture*, edited by Hal Foster, 16–30. New York: New Press.
- Hart, K. 1973. "Informal Income Opportunities and Urban Employment in Ghana." *The Journal of Modern African Studies* 11, no. 1 (March): 61–89. doi: 10.1017/s0022278x00008089.
- Harvey, D, ed. 2000. "The Insurgent Architect at Work." In *Spaces of Hope*, 233–255. Edinburgh: Edinburgh University Press.
- Hou, J. and M. Chalana, eds. 2017. "Untangling the "Messy" Asian City." In *Messy Urbanism: Understanding the "Other" Cities in Asia*, 1–22. Hong Kong: HKU Press. doi: 10.5790/hongkong/9789888208333.003.0001.
- Jacobs, J. 1961. *The death and life of great American cities*. New York: Random House.

Postcolonial Possibilities of Architectural History

- Kubler, G. 1962. *The Shape of Time: Remarks on the History of Things*. New Haven: Yale University Press.
- Lefavre, L. and A. Tzonis. 2003. *Critical Regionalism: Architecture and Identity in a Globalized World*. Munich: Prestel.
- Lefebvre, H. 1991. *The Production of Space*. Translated by Donald Nicholson-Smith. Oxford: Blackwell.
- Mirafteb, F. 2016. "Insurgent Planning: Situating Radical Planning in the Global South." In *Readings in Planning Theory: Fourth Edition*, 480-498. Hoboken: Wiley. doi: 10.1002/9781119084679.ch24.
- Moholy-Nagy, S. 1961. "The Future of the Past." *Perspecta* 7: 65-74. doi: 10.2307/1566867.
- Rapoport, A. 1975. *House Form and Culture*. Englewood Cliffs, NJ: Prentice-Hall.
- Rowe, Colin and Fred Koetter. 1975. "Collage City." *Architectural Review* 158, no. 942: 66-90.
- Roy, A. 2009. "The 21st-Century Metropolis: New Geographies of Theory." *Regional Studies* 43, no. 6 (August): 819-830. doi: 10.1080/00343400701809665.
- Roy, A. 2016. "Who's Afraid of Postcolonial Theory?" *International Journal of Urban and Regional Research* 40, no. 1 (January): 200-209. doi: 10.1111/1468-2427.12274.
- Rudofsky, B. 1965. *Architecture Without Architects: A Short Introduction to Non-Pedigreed Architecture*. Albuquerque: University of New Mexico.
- M. Bayoumi and A. Rubin, eds. 2019. *The Selected Works of Edward Said, 1966-2006: Expanded Edition*. New York: Vintage.
- Summerson, J. 1969. *Georgian London*. Harmondsworth; Middlesex: Penguin Books.
- Venturi, R. 1977. *Complexity and Contradiction in Architecture*. New York: Museum of Modern Art.
- Viollet-Le-Duc, E. E. 1877. *Lectures on Architecture*. Translated by B. Bucknall. Philadelphia: Franklin Classics Trade Press.

THE 'UNINTENDED' CITY: A Case for Re-reading the Spatialization of a Princely City through the 1898 Plague Epidemic

Sonali Dhanpal
Newcastle University

Abstract: Cities have witnessed a surge in attention from urban scholarship in what is now referred to as the 'urban turn' in South Asian studies. In recent years, colonial Presidency capital cities such as Bombay, Calcutta, and Delhi and their mutually constitutive architecture and urban history, have received significant recognition. The urban history of nominally sovereign, princely states and their respective capital cities, however, have been relegated to regional histories, sustaining limited inquiry. This paper, therefore, focuses on colonial urbanism in one such understudied princely city, Bangalore, the administrative capital of the princely state of Mysore. Through the plague of 1898 and the extraordinary intervention measures it occasioned, the paper investigates spatial patterns in parts of the city that fell under British jurisdiction, during a critical period in the state, between when princely rule was reinstated in 1881 until the aftermath of the bubonic plague that struck the city in 1898. The British controlled parts of the city had been envisioned to reflect order and authority but also *difference* from its native counterpart. Such vision, became a means of and reason for social control in the British controlled areas, resulting in urban segregation that often overlapped with religious, ethnolinguistic and caste segregation prompting the creation of the metaphorical 'unintended city'. By examining these unintended pockets, this paper seeks to demonstrate ways of thinking about architecture and urbanism, beyond social privilege and aesthetics of envisioned, formal, master plans. It will reveal a more complex story than that of a partitioned original settlement or Pettah, and the European 'white city' that colonial administrators commonly ascribed to its spatialization.¹ After the plague, "improvement" projects became central to the imagination of the city, twinning as both sanitary and moral reform. But capitalist imperatives and laissez-faire economics compromised planning measures, making available such improvements to limited populations, resulting in paradoxical outcomes. Instead of focussing on these improvement schemes, this paper questions imposed paradigms in architectural history by reconstituting the object of investigation and recognizing ephemeral spaces, such as segregation camps and hospitals, both "temporary" and "permanent". It argues that the spaces conceived from these momentary exchanges caused by disruptions such as the plague, are key to understanding space making in Bangalore city, before formal improvement schemes were introduced. There exists a lacuna of unadulterated self-representation of marginalised, non-local, migrant inhabitants. This paper, by following the plague, allows examination of their lives to some extent, through the spaces they inhabited, were limited to, and those that were excluded from, in this process. Employing a wide variety of unexamined archival sources that range from gazetteers, plague reports and sanitary regulations that have hitherto not been used for the purposes of a spatial enquiry to examine the city, it provides a rich depiction of the 'unintended' city and its inhabitants.

Keywords: Princely urbanism, segregation, plague, epidemic, disease, improvement projects, ephemerality

INTRODUCTION

Scholars of South Asia in recent years have turned to the city, previously suppressed in historicist discourse, in order to understand society, as spaces of both, power and difference (Prakash 2002). There has been a surge of interest in the making of modern south Asian cities and many have focused on rethinking the nature of colonial urbanism in British India. Princely states and their capital cities, such as Mysore, Hyderabad, and Baroda, were the focus of colonial urban development, just as presidency capitals of Delhi, Calcutta, and Madras.² Despite their distinct urban identities under colonial rule, scant attention has been paid to the development of princely cities

and the enduring assumptions about colonial cities continue to be ascribed to them.³ The colonial "dual city" basis of separation still persists in Bangalore perpetuating the physical separation between what was thought to be a predominantly European settlement, from its native counterpart. This paper therefore takes its cue from recent scholarship on British India that has dismantled the paradigmatic image of the racially partitioned Manichean 'dual city' model (King 2006).⁴ The limitations of the enforced physical and cultural incommensurability between the 'white town' (European) and 'black town' (Native) provides an opportunity to reconsider to what extent colonial

urbanism constituted a coherent set of ideas, especially in the case of princely cities such as Bangalore, a product of 'indirect' British rule and undoubtedly a very different political landscape. Studying princely cities allows examination of forms of urbanism, not as alternatives to colonial cities, rather, to explore their production as heterogeneous developments. By the late nineteenth century, Mysore, which had previously been conceptualised as the royal capital, was divested of its administrative associations to Bangalore and a new division of labour was achieved between the two cities (Nair 2011). The 1898 plague set in motion apparatuses of invasive sanitary measures and radical town planning schemes. Bangalore during this period, therefore, presents an interesting opportunity to examine a rapidly changing landscape that inscribed political, social and economic hierarchies of caste and class, upon its newly expanding urban terrain.

This paper is divided into three parts. The first provides a closer examination of the residential pattern of the city's Civil and Military Station (C & M Station), to reveal a more complex story.⁵ It will show how assertions, such as the station being primarily European or a vision of order, were more figures of political desire on the part of colonial administrators than accurate descriptions of urban cultural geography.⁶ The station by the late nineteenth century became a labour market attracting new migrants, often impoverished, who found themselves 'set apart' in squatter settlements from relatively more planned areas. Neither were the existence of such populations and the spaces they inhabited officially acknowledged, nor was the state's role in setting them apart. This has resulted in a paucity of records about such migrant populations, with little or no forms of unadulterated self-representation of speaking in their 'own' voices. The second part of this paper fills a gap in literature by examining their lives to some extent, from colonial records such as Mysore State gazetteers and plague reports. Several books on modern South Asian urban history, suggest that urbanism in colonial South Asia was fundamentally about the spatial segregation of populations.⁷ They situate urban segregation as the key antecedent to class segregation, functioning as a means of and reason for social control, often overlapping with religious, ethnolinguistic, and caste segregation (Beverley 2011). It was on the occasions of outbreaks of disease such as the third plague pandemic that struck Bangalore, where segregation of such populations emerge in records, albeit most often, only indirectly. Whilst accepting that Indian society did self-segregate to an extent, this part will show how segregation was not always voluntary, by exposing a hidden history of how 'setting apart' of some populations was state induced, often due to paradoxical

interventions such as those intended for sanitation. These populations that were set apart, have not been the focus of previous studies of the city. The third part of this paper will reflect on the spaces they inhabited, were limited to, and those they were excluded from, during the plague and its immediate aftermath. Prompted by research that has radically reconstituted the object of investigation from the 'permanent' inscription of the built environment as key to understanding political agency, it too questions paradigms in architectural history by focusing on ephemeral spaces and 'temporary' traces of material culture created by disruptions such as the plague.⁸ The records used are often disparate and come with many large gaps, nevertheless this paper will provide a rich depiction of populations that are not commonly discussed in the history of the Mysore state, revealing a city etched with spatial inequalities.

THE UNINTENDED CITY

A swathe of parkland cleaved the C & M Station and administrative buildings from the Bangalore city or *Pettah* (figure 1). The Station also fell under the control of the Commissioner of Bangalore until 1881 (when the princely state was returned to indirect rule after a period of sixty years) and Bangalore city was under the princely state of Mysore, perpetuating the physical separation between what was thought to be a predominantly European settlement, from its native counterpart. The notion of *difference* between them, was furthered by representations of everyday life in the C & M Station and described in various colonial sources as being divorced from that of the native inhabitants in the Pettah. British orientalist Lewis Rice described the streets of the pettah to be "very roughly paved and nearly always abounding in filth" (1897, 263). In striking contrast, he described the Station as having broad, straight tree lined avenues intended for parades of wheeled vehicles or spectacles of military power (figure 2). Accounts of the city such as the Census of India 1893 (Mysore) indicate strong linguistic and cultural differences between the two. A section on religion in the census claimed that the majority of the Christian population in the Mysore state, both Europeans and Native Christians, resided in the station, a circumstance it accounted for by the presence of the British Military garrison (Narasimmiyengar 1893, 58). Such depictions, consistently drew cultural and visual comparisons between the metaphorical "east" and "west" (Ranganathan 2018).

The divisions between the Bangalore city and the C & M station however, just as Calcutta's 'white' town and 'black' town, were neither complete nor static and they were far from autonomous entities (Chattopadhyay 2005). The economic, political and social condition of colonial culture penetrated the insularity of both,

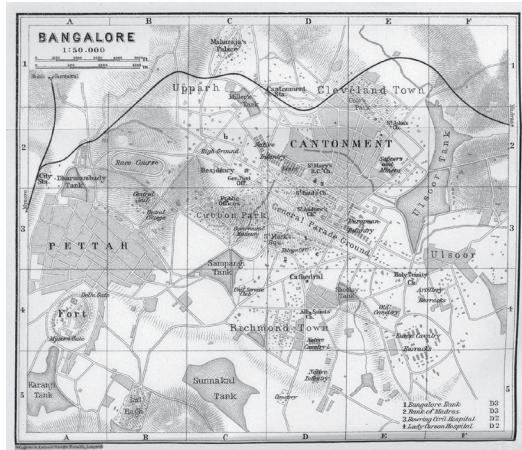


Figure 1: Map of Bangalore, on the left is located the Pettah or Bangalore city, on the right is located the Cantonment that became the C & M Station and the two are seen separated by parkland. (Indien: Handbuch Für Reisende: Karl Baedeker in Leipzig)



Figure 2: Aerial view showing landscaped avenues and roads leading to the Attara Kaccheri or the Mysore State High Court from the Kannada film 'Mane Katti Nodu' of Bangalore in 1948. (Economic Times 2016)

although at different levels and to varying degrees. Accounts such as P.R Caldwell's Report on the outbreak of plague in the C & M station in 1899 attest to this. His descriptions note their proximity and relationship

... the City of Bangalore, which is a portion of the Mysore State is situated so close to the Civil and Military Station that, were they under the same jurisdiction, the two would undoubtedly form one city. ... the intercourse between them is so diverse, as so many of the inhabitants of each have ties of occupation or of relationship in the other. ... (Caldwell 1899, 1)

Despite their mutually dependant relationship, representations in historiography were rooted in the colonial civilising narrative to present the cantonment as better developed than Bangalore city, due to

British presence. Municipal services in the city were underfunded by the colonial government. Until 1895, only half as much per capita was spent on public works and conservancy (house-to-house sewage collection) in the native pettah as compared to the C & M station (Ranganathan 2018). Piped water was introduced to Bangalore city only just before the plague and water was provided and sold from Dharmamabudi Lake through troughs and basins, increasing incidents of contamination and illness. This was in contrast to the C & M station which had secure supplies of water (Nair 2005). The disproportion in allocation of resources between Bangalore city and the C & M station as Malini Ranganathan describes, were not accidental. The intent was to frame poverty as inexorably racial and cultural, innate to the habits of colonial subjects, rather than a result of the workings of racial and imperial capitalism. In this way, colonial discourse served as moral justification for state projects of accumulation and control (Ranganathan 2018).

The colonial government projected the C & M Station to be a well laid out settlement, with large avenue roads, churches and large buildings, the reality however, was far more complex. There certainly were well-spaced areas for European occupied sprawling bungalows in areas such as Richmond Town and Langford Town (an example of one such bungalow seen in figure 3 & 4), but none were too far from native quarters or lines within the station that provided vital supplies of domestic and other labour (Ranganathan 2018). The station that had been designed to function as a military cantonment in the early nineteenth century, gradually grew to become a labour market, attracting a large number of migrants induced by opportunity and employment. The anomalous demography of the station, also allowed sociability beyond the limits of traditional caste and occupation hierarchies, that other 'native' areas were bound to, thereby attracting migrants of specific endogamous groups. They formed the 'unintended city' that was 'never a part of the formal master plan but always implicit in it' (Nandy 1998). This unintended city consisted of a growing number of poor in slums and streets that provided cheap labour and services without which the official C & M station would not survive (figure 5). Take, for example, a population of 3000 butchers, fowl and egg dealers and fish sellers recorded in the census specially catering to the large military cantonment in the C & M station (Narasimmiyengar 1893). Such occupations were practiced by specific castes such as Gollas also known as *Gauliga* or *Kavadiga*, who were unlikely to have lived in Bangalore city, where predominantly upper caste Hindus and Jains resided, and food suppliers engaged predominantly in grain and vegetables

catering to their dietary restrictions dictated by caste (Narasimmiyengar 1893, 349).⁹ As Nair (2017) notes, civilian groups such as the 'Labbes, Mudaliars and lower caste menials' came from Tamil speaking areas of the neighbouring Madras presidency (Nair 2005). The station also had a high proportion of 'Mussalmans' who according to the Census of 1893 collected in the station because they were "unrestricted by the iron barriers of caste and hereditary and traditional professions" (Narasimmiyengar 1893). The existence of the slums in Blackpully, north of the station's parade

ground, Ulsoor, quarters near Shoolay circle and the Arab lines had been designated as 'native quarters'¹⁰ when the station was laid out. Their presence was not due to a failure of planning mechanisms, or the 'unreformable' traits of Indians, but owed to the structural features of undemocratic, unequal forms of state regulation that had prompted their existence. Yet, administrators would not acknowledge their existence, officially, nor their role in 'setting apart' such civilian groups. In doing so, they would forego blame for the material conditions of such populations but also obscure them from the history of the C & M station.

PARADOXICAL IMPROVEMENTS

In the nineteenth century, "improvement" infused urban planning as leitmotif for twinned sanitary and moral reform of the working poor in Victorian Britain, as it came to define planning in the colonies. Improvements, however, were 'radically transfigured' because native subjects were construed as being "irreducibly different" from their European counterparts (Legg 2008). As Kidambi (2007) suggests in his study of colonial Bombay, the plague was framed as "a disease of locality", meaning that the infection was stubbornly believed to be in-situ and stem from cultural pollution. Similar ideas are unravelled in Swati Chattopadhyay's *Calcutta* (2005), where she notes that European medical practitioners in India claimed with certainty that disease developed along foreign principles in the tropics and that tropical disease affected Europeans differently from native inhabitants. The plague that struck Bombay in 1896 found itself in the Mysore State in 1899.¹¹ Tellingly, the engineer in charge of plague-proofing the city during this period, J.H. Stephens (1914), wrote: "... while so many Mohammedens died, the plague hardly touched the English. It took some time for these people to understand that the principal cause of all the trouble was insanitary habits and manner of living". Notwithstanding that the plague was transmitted by rat fleas much like in other cities at the time rather than odours wafting from overcrowded dwellings, the bodies and homes of poor native subjects (Chandarvakar 1998; Kidambi 2007).¹² P.R Caldwell's report on the outbreak of plague in the C & M Station in 1899, validates similar ideas. He carefully disassociates the plague in Bangalore city from its outbreak in the C & M station. It is no surprise that we learn from it that plague measures deepened racial segregation, since it makes clear that Europeans, except the officers of the native regiments, were spared of the inoculations (1899, 22). At the level of the city, he ascertained that mortality rates were different among races and religions using "scientific data" (figure 6), belabouring that Europeans escaped very lightly, despite the former living in poorer

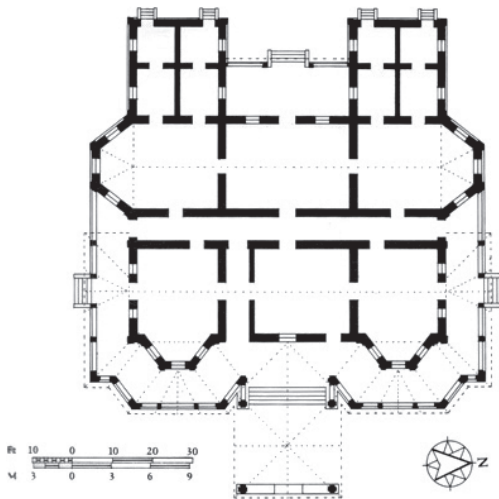


Figure 3: Plan of 6 Richmond Road, a bungalow in Richmond Town. Courtesy: Janet Pott, *Old Bungalows of South India*. (London: The Author, 1977, 33)



Figure 4: View of 6 Richmond Road. Courtesy: Janet Pott, *Old Bungalows of South India*. (London: The Author, 1977, 33)



Figure 5: Scrap metal traders in Blackpully Source: Stephens's Square Merchants' Association. (<https://www.livemint.com>)

cramped areas in cheek by jowl housing, without the amenities afforded to the latter. He also established that Muslims, on the whole, suffered more severely.¹³

By the late 19th century, there was a gradual shift in colonial disciplinary attitudes towards the city from the control of spaces to the regulation of bodies, through 'colonising the body' (Arnold 1993; Beverley 2011).¹⁴ In Chattopadhyay's *Calcutta* (2005) and Kidambi's *Bombay* (2007), a picture of colonial urbanism developing a repertoire of rhetoric and practices begins to emerge, where sanitary threat and contagion were found to be located in the neighbourhoods and dwellings and later in the bodies of the poorer segments of the subject population. Just as in *Calcutta* (Chattopadhyay 2005), colonial officials in the Mysore state drew upon ethnographic data and theories of disease to reorganise and regulate the C & M station. A great deal of attention was paid to frame the 'locality' as the focus of governmental attention. The station was divided

into convenient units for such an exercise in 1894 indicated in figure 7, where the coloured areas show the limits of the station. It was divided into 14 circles, 24 sub-divisions and a further 162 blocks containing 100 houses. Each circle was placed under a superintendent and each block, a supervisor (Caldwell 1899). The results of such exercises, inextricably interlaced with caste and class, are the few extant sources from which we can uncover the group identities of these civilians.

Caldwell's Report on the outbreak of plague in the C & M station notes in detail the areas where, and the populations on whom, the first plague preventative measures were exercised. Knoxpet, an area 'inhabited almost entirely by "Pariahs" with an "extremely low situation" and "always an unhealthy quarter" with cases of plague recurring persistently, was evacuated.¹⁵ Over 1,700 inhabitants were removed to a camp built on high ground (Caldwell 1899, 24). The disease was noted to be the worst in Blackpully, a locality where urgent attention was required. Blackpully was the largest such pocket covering 51.53 acres with 1,952 occupied houses, 2,700 families and with over 12,000 people constituting a seventh of the population of the entire C & M station (seen on map demarcated by a neutral tint). This area was also the most densely populated part of the station with a 'large number of Mahomeddians'. During the first severe outbursts of plague, the Munisami lane where the Gollas¹⁶ milkmen lived, suffered very badly. It was from here that the plague was said to have spread quickly from house to house, specifically on one side of the street, where houses abutted each other (Stephens 1914, 78). The houses in South Blackpully were eventually demolished under the Land Acquisition Act, in 1906. Over 594 houses in total were demolished (32 percent of the houses) were dismantled and 436 families were removed. Owners of the houses that were left untouched or partially demolished were pushed to make improvements themselves (All India Sanitary Conference Vol 2, 1913, 114). Another locality, the village of Venarpett that was inhabited by *Dhobis*¹⁷ was also evacuated. The recurring incidence of disease here, despite evacuation, was said to pose danger to the Artillery lines and its 543 inhabitants were removed to a camp nearby. Nilsundra, a village noted to be 'composed entirely of a respectable class of 'Mohammadans' was disinfected but not evacuated (Caldwell 1899, 6).

The evacuations, in Knoxpet, Frazer Town and Vennarpet targeted Pariahs, Gollas and *Dhobis* respectively, groups that were marginalised both socially and officially. These specific groups were identified as the source of contagion and made the focus of plague proofing measures. Subject to inoculation, displacement and dispossession, they were often not adequately rehoused or compensated. Take for example, Knoxpet,

APPENDIX XVI.
BANGALORE, CIVIL AND MILITARY STATION.
Mortality by Races from 15th September 1898 to 28th February 1899.

	Population.	Plague attacks.	Percentage to Population.	Plague deaths.	Percentage to Population.	Total Mortality.	Percentage to Population.	Ratio per 1000.
Europeans ...	4,985	18	3	12	2	37	74	16
Eurasians ...	2,649	47	17	35	13	77	29	63
Native Christians.	10,268	414	4.4	320	3.1	517	5	109
Mahomedans ...	23,892	871	3.6	789	3.3	1,681	7.9	172
Hindus & others.	68,287	2,050	4.5	2,142	3.7	3,611	6.2	135
Total...	100,081	4,000	4	3,298	3.3	6,130	6.1	133

Figure 6: Appendix XVI Bangalore, Civil and Military Station
Source: British Library Courtesy: P R Cadwell, Report on the outbreak of plague in the Civil and Military Station, Bangalore 1898-99. (Bangalore: Paragon Press, 1899)

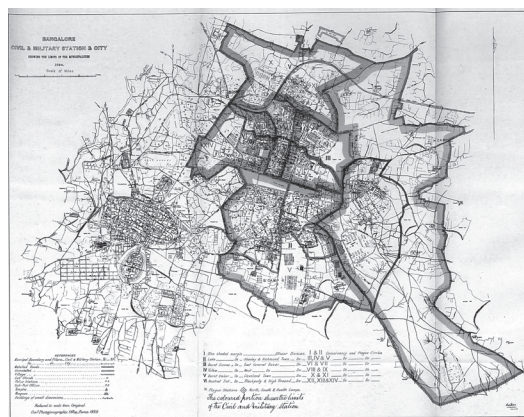


Figure 7: Limits of Municipalities showing division into 14 circles (1894). Source: British Library Courtesy: P R Cadwell, Report on the outbreak of plague in the Civil and Military Station, Bangalore 1898-99. (Bangalore: Paragon Press, 1899)

where despite evacuation following the plague in 1898, rebuilding took place only in 1923 (Nair 2002). In Blackpully and Nilsundra, the extant Muslim population were the focus of improvements, but interestingly the 'respectable class of the Mohammedans' in Nilsundra were subject to only disinfection, as opposed to evacuation or demolition. Caldwell noted that the residents in Nilsundra were spared of complete evacuation because the population was clearly not used to living in huts, so residents only moved out during the operation of disinfection (Caldwell 1899, 6). The inhabitants of Vennarpet were subject to evacuation for a fortnight and, after thorough disinfection of their homes, inhabitants were allowed to return (6). Conflict, violence and force were the norm and various castes and classes (often overlapping) were subject to varying degrees of control. Racialized improvement targeted the health and moral propriety, as well as the property, of poor-low caste non-Europeans. One could argue that it was precisely because of their vulnerable disposition, both economically and socially, that the municipality increasingly targeted marginalised groups. Despite uneven improvement measures that often resulted in dispossession and displacement, elites and officials would never cease to insist that improvements were beneficial for these populations. An approach not unfamiliar to Stuart Mill's ideas of utilitarian imperialism, where colonial intervention by a class of "philosophical legislators" was seen as necessary for the improvement of colonies (Bell 2010).¹⁸ Identifying these areas of uneven improvement measures and poverty in the C & M station paints a picture, different from the image of ordered residential layouts that replaced these localities.

EPHEMERAL SPACES

The ideology of improvement was institutionalised in the City Improvement Trust Board and sanitary housing schemes arose in the aftermath of the plague, but produced paradoxical results.¹⁹ On the one hand, the bungalow within a compound, became leitmotif for twinned sanitary and moral reform in localities such as Frazer Town (figures 8 and 9).²⁰ On the other hand, capitalist imperatives, which privileged profit over improvement, made available the bungalow and the bourgeois comfort of a planned locality available to limited populations. Congested parts of Blackpully were demolished (figure 10) giving way to planned localities, such as Frazer Town in 1906, Richards Town and Cox Town (Thompson 1920). All three layouts, had electric lights, wide roads and conservancy facilities. Such amenities led to quick gentrification, as 'well to do residents' soon took the place of the poor who had been forcefully displaced to make way for them (Nair 2005). Improvement, as in other colonial cities,

was thus not about improving, or remedying sanitary conditions but enhancing the commercial value of land. This in turn meant that those evicted were unable to actually access land, localities and housing that were made healthful or sanitary. In this section, I focus on the spaces that populations who were displaced and dispossessed were taken to, when framed as vectors of disease. Owing to the paucity of the whereabouts of



Figure 8: "Near View of Two Compound Cottages" in Frazer Town. Source: Stephens, J. H. (1914). *Plague-Proof Town Planning in Bangalore, South India*. (Madras: Methodist Publishing House)



Figure 9: View of the development of Frazer Town titled "View of a block of buildings in erection." Source: Stephens, J. H. (1914). *Plague-Proof Town Planning in Bangalore, South India*. (Madras: Methodist Publishing House)



Figure 10: Portions of Blackpully cleared to make way for Frazer Town. Source: Stephens, J. H. (1914). *Plague-Proof Town Planning in Bangalore, South India*. (Madras: Methodist Publishing House)

marginalised, non-local, migrant communities, I draw attention to temporary spaces, such as plague sheds, segregation camps and plague hospitals that they were moved temporarily. Few have considered the cumulative impact of a large number of “temporary” interventions operating with the “permanent” infrastructure of the city. Recognizing the impact of short-lived structures and ephemeral spaces produced through the plague can help move beyond the social privilege and aesthetics of envisioned, formal, master plans commonly understood in the development of Bangalore.

In an address to Her Highness, the Maharani-Regent at the Dasara Representative Assembly, the Dewan of Mysore Seshadri Iyer (1899) addressed the outbreak of the plague in various parts of the state. He described the precautionary measures taken by the government.²¹

... the passing of the Epidemic Diseases Regulation and the framing of Rules thereunder, the opening of railway and frontier inspection stations and outposts, the examination of passengers by rail and road, the detention, observation or escort to their destination of such persons as arrived from infected areas or were suspected of carrying infection, the establishment of temporary plague hospitals and segregation and health camps at centres likely to become infected and the carrying out of special sanitary improvements in towns and villages ...

He also outlined the measures for its prevention and suppression:

... provision was made in government plague hospitals for the treatment of the sick. Accommodation was provided in camps for contacts and persons living in infected houses...A large number of houses condemned as unfit for habitation were demolished in the Bangalore city and the congested portions opened out by the removal of many more... Compulsory segregation restored to for some time but was afterwards abolished in all locality's except Bangalore city. A large number of health camps were established. Free issues of timber and bamboos were made to the poorest classes to enable them to camp out, relief works for the indigent wherever necessary. Advances to government servants of a year's pay were sanctioned in the Bangalore city to enable them to build houses in the new extensions, and of three months' pay in certain infected taluks for putting up sheds ... (Address of the Dewan of Mysore 1899, 254-55)

In short, at the risk of oversimplification of this speech, Sheshadri Iyer presented how the colonial state, through its organised bureaucratisation, had a firm grip over the situation. The actions to combat the plague as set out by him were, firstly to frame control over the disease through governmental regulations; the Mysore government passed the Mysore Epidemic Diseases Act, II of 1897. As Stephen Legg discusses in relation to venereal diseases in Indian cantonments ‘municipal laws to challenge disorderly lives’ (Legg 2012).²² The second was to isolate the cases of disease using a

repertoire of urban discipline that produced the effect of policing and surveillance as a method of containment. Lastly, and most significantly, were solutions to contain the disease that were almost always spatial, because all health measures from detention, segregation, treatment and even isolation involved architectural solutions. Neatly marked plague quarantines, the issue of building materials to build shelters, and the long term exercises in urban planning that proceeded it, are all part of the colonial “will to improve” (Li 2007).

Concerns about the plague were manifest in the obsession with boundaries that were used to convey the “impression of constant surveillance”. Poorer city dwellers were thereby systematically subjected to what Legg (2012) describes as “sanitary surveillance”. The C & M station was surrounded by three health camps, South, North and Military hospital (Caldwell 1899, 19) with ten plague stations marked by X, creating a spatial boundary of surveillance in the city, as seen in figure 11. Blackpully had a concentration of seven such camps indicating again that the focus of the surveillance was on this locality. A detention camp was established at railway stations and all persons who came from infected areas and those who ‘could not be trusted to report themselves’ were intercepted and forcefully detained (Caldwell 1899, 14). The departure from the town of infected persons without passes was prohibited from the cantonment and the city railway stations, until complete disinfection as described was undergone (Caldwell 1899,12). The outcomes of such theatrics were aimed at producing a pacifying ‘moral effect’ among populations. But disinfection was ineffective unless the afflicted were prevented from settling elsewhere, which would certainly spread the disease over a wider and less regulated area. Governmental attention therefore

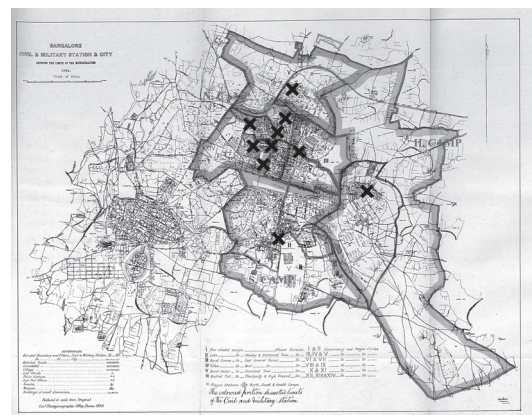


Figure 11: Limits of Municipalities (1894). Map Courtesy: P R Cadwell, Report on the outbreak of plague in the Civil and Military Station, Bangalore 1898-99. (Bangalore: Paragon Press, 1899; edited by the author)

shifted beyond disinfection, and segregation emerged as the immediate practicable solution to controlling both the disease and poorer populations.

Segregation was one side of double surveillance that brought the convalescent within the purview of the state, and segregation policies that monitored the afflicted within camps and hospitals, was the other. The layout of one such segregation camp is seen in figure 12; separated from the hospital by a barbed wire fencing are the camp, two kitchens, latrines and a disinfection room. A symbol of a native infantry guard indicated near the camp shows that it was likely to have been guarded. The image shows in detail the layout of the South Camp hospital, one of the three hospitals for the treatment of plague cases (Caldwell 1899, 17). The plan is certainly extensive, manning the entrance is a police sentry and a disinfection room. Wards allocated for both male and females and those built by Sappers and Miners (native infantry), along with servants' quarters, hospital kitchens, dedicated convalescent huts in two locations and a sisters' staff go-down, are also seen present.²³ The wards and convalescent huts were arranged around a central dispensary and a nurse's night duty room. Towards the west, were the quarters for nurses, assistant surgeons, drugs stores and an office located near the only other exit from the hospital. Segregated wards of the 'caste' hospital with a separate cook house, a latrine on the east, and another area cordoned off as 'enclosed huts for purda women' with kitchen and latrine areas were also present. Various indications of water sources as 'taps', *dhobi* areas were also included and show what appears to be a well-equipped hospital. Captain Leumann describes the South Camp hospital to be the "best built and best arranged plague hospital he has seen in a considerable experience in such institutions" (Caldwell 1899, 19).

However well-built and arranged, segregation induced fear in the afflicted population and the "horrors of segregation" were always referred to as the worst features of the plague (Caldwell 1899). The Epidemics Act 1897 legitimised the state government to take special measures and prescribe regulations when confronted with a dangerous epidemic.²⁴ The nature of the Act allowed alteration of existing law, if thought of as inefficient, and thereby exert control over bodies of the afflicted by any means it thought necessary, in the name of preventing an outbreak. Those infected by the plague, their entire family and neighbours, were forcibly removed to distant camps such as these. Revealingly, Stephen notes that "the state of young children and young women under these conditions can be better imagined than expressed", showing the heavy burden that many families endured through such forced separation. The ephemeral architecture of

borderlands, and displaced persons camps, are thought to be a more recent concern.²⁵ Both the South Plague hospital and segregation camp, highlight the fragile spatial and material conditions experienced by forcefully displaced persons in 19th century colonial Bangalore. All entry points were guarded to prevent occupants from leaving. A mortuary located within the compound, in the vicinity of the hospital to the segregation camp where plague afflicted were detained, must have provided for a macabre atmosphere. Plague precautions also violated sentiments, since caste and religion were afforded scant recognition and seen as "superstitious" obstacles for the implementation of essential and scientific sanitary operations (Arnold 1993). Removal of Muslim and Hindu women, even if there were separate spaces for *Purdah* women in camps such as the one in figure 12, directly violated the idea of *gosha* and some Hindu caste groups respectively.²⁶ A directive from Bombay's surgeon-general had openly stated that caste "prejudices" should be observed as far as possible, but could not be allowed to stand in the way of essential sanitary and medical measures (Arnold 1993). As seen in the spaces of the plague hospital and described by Caldwell, caste and non-castes were forced to brush shoulders in the camps, an interaction which would have been avoided as far as possible, if not for the camp. The erasure of these structures perhaps lies in the impermanence of the materials used to construct these spaces, despite their leaving a permanent impact on the city.²⁷ These structures are also likely to have been razed to ground, to make way for more 'permanent' settlements as the city expanded.

Caldwell notes that "the people dreaded the plague regulations more than the disease itself" (Caldwell 1899, 19). He notes apathetically that he could not understand what the "horrors" were and why the natives feared segregation as they did, arguing it was the timidity of the people. But the detainment in segregation camps was often indefinite, even if inoculated, because the effects of inoculation and the duration of the infectious stage were not wholly known (Stephens 1914; Caldwell 1899). Inoculation was at best only a protection and, as such, its effects were short-lived because it did not tackle the cause of the plague (Stephens 1914). In addition, The Act also imposed a penalty to any person disobeying any regulation, which meant that the person had committed an offence punishable under section 188 of the Indian Penal Code (45 of 1860) (The Epidemic Diseases Act 1897). Fear of non-consensual detention, draconian penalties and a general mistrust of the colonial government's actions, lead to multiple instances of subversion and many of the plague-infected, secreted and concealed themselves, till death (Caldwell 1899). The lack of acknowledgement of cultural differences of

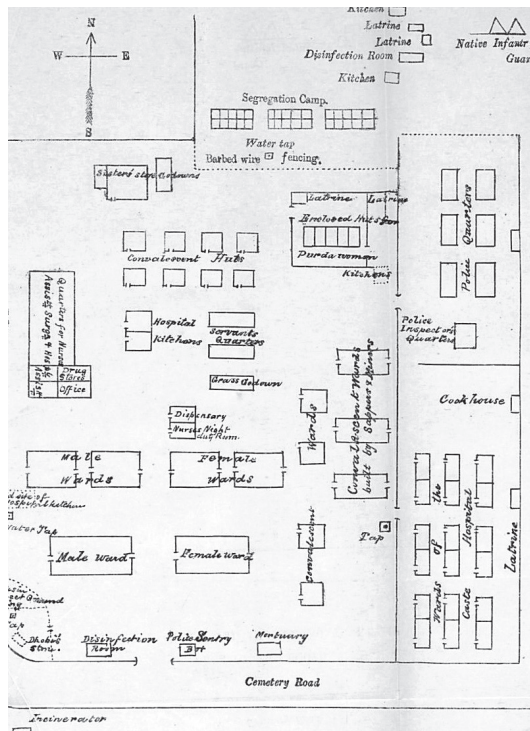


Figure 12: Plan of the South Plague Hospital and Segregation camp Source: P R Cadwell, Report on the outbreak of plague in the Civil and Military Station, Bangalore 1898-99. (Bangalore: Paragon Press, 1899)

caste and religion were also the source of resistance to invasive plague measures, and sometimes elicited violent reactions and responses (Nair 2009). Epidemiological evidence had come to prove that the segregation was ineffective in India. Segregation was neither worth the trouble nor the expense since only seventy-six cases of plague were found amongst those detained in camps in the Mysore State. It was finally recognised by the government as ineffective and all District Medical Officers unanimously condemned it as a failure (Caldwell 1899, 20). The failure of segregation and the adoption of alternative methods reveal that plague proofing was a process of trial and error, responding to events as they unfolded as opposed to having been planned ahead of time. Such methods and measures could be implemented without accountability precisely because the populations that they focused on, were marginalised groups with precarious materialities.

The plague brought racial and cultural prejudices to the fore, exacerbating caste and religious prejudices. Although Haffkines' method of inoculation had been discovered, it was not pushed in the early stages because the security it afforded was not fully understood and treatment in some cases was either considered to be too severe or in other cases too mild

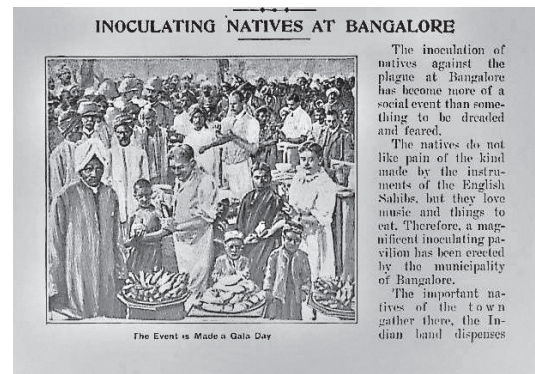


Figure 13: Plague inoculation at Bangalore. Sweets were dispensed and music was played as the inoculation was done c.1908. (Digitized by google from University of Minnesota)

(Stephens 1914). Inoculation incapacitated residents from work for a few days, and attempts were made to encourage or even push people to pursue treatment. In some cases 'leading Hindu citizens' came forward to be publicly inoculated to set an example to other civilians. In other cases, wealthy citizens *paid batta* to the poor people inoculated.²⁸ Paying *batta* can be argued to have coerced consent of the many who were displaced and dispossessed. It was not just the bodies of the poor, that became the subject of inoculation, it was the non-castes who were first subject to them (figure 13). The image above paints a picture of the treatment eventually becoming a social event, rather than something to be feared. "The natives do not like the pain of the kind made by the instruments of the English Sahibs but they love music and things to eat. Therefore a magnificent inoculating pavilion has been erected by the municipality of Bangalore". Stephens noted that at the next outbreak of plague, it was found that nearly all non-castes were exempt from inoculation and only the caste people were easy victims. The bodies of the 'non-caste' set precedent for the 'caste' people to come forward in large numbers. Thereafter, a vigorous campaign of door to door inoculation for so called 'respectable castes' was inaugurated (Stephens 1914). These examples show spatial dimensions of the plague, but are also revealing of how forced plague measures were not for all the afflicted and the populations on whom they were harshly enforced.

CONCLUSION

The precarious materialities of the plague stricken, and their continued harassment, drove them from the C&M station and the city, but also from the historiography of twentieth century India and contemporary research. Following the plague in this paper through these telling records, uncovered spatial inequalities that led to the

'unintended' city created by inconsistencies of urban governance. This contributed to understanding the spatialization of Bangalore as more diverse than the dominant narrative of 'native' original settlement and 'European' Civil & Military station commonly ascribed to it. The erasure of the populations in these unintended pockets however, can be attributed to the government's concerted effort to project the illusion of control. The plague and measures to contain it, revealed the identities of some of these populations that were in the state's purview. The measures were presented to be impermanent, but hegemonically intended to discipline and cure the plague inflicted into health and obedience. Paradoxically however, the plague became an inflecting point of colonial politics as state action was seen as unnecessary and disruptive, often leading to resistance and conflict. The impermanent traces of material culture of interventions such as segregation camps,

plague hospitals and their temporal characteristics explored in this paper give rare glimpses of the spaces to which specific groups were forced and limited. Separate spaces for people of 'caste' and other such endogamous divisions even in a segregation camp show how spaces conceived from these momentary exchanges were intended to function. Displacement had long term legacies, since those dispossessed and evicted were unable to actually access land, localities and housing that were made healthful or sanitary. This paper-provides insight into how urban space, even in a princely city, became the staging ground for colonial disciplinary violence and exclusion. It also seeks to highlight the impunity with which colonial authorities were able to do so before future policies would move from disciplining and curing the plague inflicted to a consideration of biopolitics, or the broader welfare of the population through wider planning measures.

ENDNOTES

- 1 Following Lefebvre's idea that all space is social space, from Henri Lefebvre, *The Production of Space* (Oxford: Basil Blackwell, 1991) and Foucault's spatialisation of power in Michel Foucault, *Space, Knowledge and Power* (New York: Pantheon Books, 1984), 239–56. This opens possibilities of interrogating postcolonial subjectivity through spaces that are occupied and used by those who are implicated in it.
- 2 Bangalore was renamed Bengaluru in 2014, similarly other cities in India with names owed to colonialism have also been renamed in recent years. In this paper however, I use colonial names of cities in line with the way they are referred to in archives from the period in discussion.
- 3 Recent scholarship such as Eric Lewis Beverley, *Hyderabad, British India, and the World: Muslim Networks and Minor Sovereignty, c. 1850–1950* (Cambridge University Press, 2015) and Janaki Nair, *Mysore modern: Rethinking the region under princely rule* (University of Minnesota Press, 2011) on Hyderabad and Mysore respectively that address urban development though not focused solely on urbanism.
- 4 See Swati Chattopadhyay, *Representing Calcutta: Modernity, nationalism and the colonial uncanny* (London and New York: Routledge, 2005); Prashant Kidambi, *The making of an Indian metropolis: Colonial governance and public culture in Bombay, 1890–1920* (Hampshire: Routledge, 2016); Stephen Legg, *Spaces of colonialism: Delhi's urban governmentalities* (Malden, Oxford, Victoria: John Wiley & Sons, 2008); Jyoti Hosagrahar, *Indigenous Modernities: Negotiating Architecture and Urbanism* (London and New York: Routledge, 2012) that deny any cleavage between the original settlement/city and the 'while city' that took form under colonialism.
- 5 The area was called Cantonment until 1868 after which it was officially designated as Civil and Military Station and will hereon in this paper be referred to as C & M Station. The Station operated as an independent area under the control of the Government of India.
- 6 Similar to Swati Chattopadhyay's (2005) description of the false binary of 'black' and 'white' towns.
- 7 See William. J. Glover, *Making Lahore Modern: Constructing and Imagining a Colonial City* (Minneapolis: University of Minnesota Press, 2007); Sudhir Hazareesingh, *The Making of an Indian Metropolis: The colonial city and the challenge of modernity: urban hegemonies and civic contestations in Bombay city (1900–1925)* (Orient Longman, 2007); Janaki Nair, *The Promise of the Metropolis: Bangalore's Twentieth Century* (New Delhi: Oxford University Press 2005).
- 8 Swati Chattopadhyay in her blogpost, *Mapping Ephemerality*, Platform.net, accessed March 23, 2020, [http https://www.platformspace.net/home/mapping-ephemerality](https://www.platformspace.net/home/mapping-ephemerality).
- 9 Caste Hindus are those belong to the Savarna or the four varna of the caste hierarchy, those outside the Savarna were groups considered to be without caste or 'outcaste'.
- 10 Janaki Nair (2005) referring to a study on Ashoknagar, formerly known as Shoolay and documents a relationship between private and public space that was more intimate, less well defined, and encouraged social interactions of a different kind from the wealthier bungalow that lay in the near vicinity.
- 11 After its appearance in Bombay in 1896, it soon spread across Northern India and Western India killing an estimated 10 million people.
- 12 Despite the plague occurring post germ theory, miasma theory, that held disease transmission was caused by a miasma, a noxious form of "bad air", emanating from rotting organic matter were still prevalent until the end of the 19th century.
- 13 The history of colonial medicine and epidemic diseases were entwined the nature of colonial power and knowledge that were hegemonic and coercive processes, illustrating the nature and aspirations of the colonial state itself. Charts, figures, statistics and graphs found in Caldwell's report on the plague were intended to show the Indian body and specific groups as the site of the contagion vectors disease.

- 14 David Arnold (1993) builds on Michel Foucault's Discipline and Punish, The Birth of the Clinic and Power/Knowledge elaborates on the idea of 'Colonizing the Body' where colonialism attempted to use the body as a site of construction for its own authority, legitimacy and control.
- 15 Pariah is a colonial era epithet for members of the 'lowest' of castes in India's caste hierarchies, groups that were later called 'outcastes' or 'untouchables' (Viswanath 2008). This term is used here because of the reference to this group in the report as such but is not an endorsement of this term.
- 16 According to the Mysore Census on (1911) Gollas were a pastoral indigenous caste sometimes also known as Gauliga or Kavadigas who are typically engaged in dairy and milk products they congregated in large numbers in towns or cities. In contemporary Karnataka they continue to be listed as Backward castes.
- 17 Dhobis are listed as Other Backward Castes by Government of India (GOI) but would have been considered 'low' caste in the late 19th century in the Mysore State.
- 18 An approach not unfamiliar to Stuart Mills 'utilitarian imperialism' where cases in public intervention were seen as necessary to give effect to the wishes of the persons interested. Just as India was best regulated by the expertise of the enlightened, colonial development needed to be directed by a class of "philosophical legislators" who understood the art and science of political economy and recording the duty to seek improvement of humanity. Duncan Bell (2010) on John Stuart Mill on Colonies.
- 19 Similar to Delhi and Bombay where the search for low costs systematically drove Trust schemes in ways that that undermined sanitation (Kidambi 2007,89-113) Legg 2012,159-209).
- 20 The bungalow in this context can be described to be an independent house set within a compound. See Desai, M., Desai, M., and Lang, J., *The bungalow in twentieth-century India: The cultural expression of changing ways of life and aspirations in the domestic architecture of colonial and post-colonial society*, United Kingdom, Ashgate Publishing, 2012.
- 21 The reaction to the plague by the colonial government (and thereby princely states) where it launched itself into a series of far reaching measures was surprising given the previous reluctance to provoke public opposition and unwillingness to spend more than was absolutely necessary on public health. But such intervention was triggered by a combination of domestic and international pressures, by political and medical considerations, without which the GOI would have been far more reticent and unlikely to have adopted such draconian measures (Arnold, 1993).
- 22 On February 4th, 1897, Lord Elgin rushed through his council with minimum debate or consultation, and gave his viceregal assent to introduce "An Act to Provide for the better presentation of the Spread of Dangerous Epidemic Disease" which applied to the whole of British India and took immediate effect (Arnold, 1993).
- 23 Sappers and miners were an engineer group of the Corps of Engineers of the Indian Army with their Head Quarters in Bangalore. They were involved in a major part of the construction activities of the Civilian and Military buildings in Bengaluru. It is difficult to establish with certainty how the wards were different convalescent huts but the fact that distinct spaces are separated show that they might have had different functions.
- 24 The Epidemic Diseases Act, 1897 Act no. 3 of 1897 4th February, 1897. The Act stated that '(1) When at any time the [State Government] is satisfied that [the State] or any part thereof is visited by, or threatened with, an outbreak of any dangerous epidemic disease, the [State Government], if [it] thinks that the ordinary provisions of the law for the time being in force are insufficient for the purpose, may take, or require or empower any person to take, such measures and, by public notice, prescribe such temporary regulations to be observed by the public or by any person or class of persons as [it] shall deem necessary to prevent the outbreak of such disease or the spread thereof, and may determine in what manner and by whom any expenses incurred (including compensation if any) shall be defrayed.'
- 25 Swati Chattopadhyay in her blogpost, *Mapping Ephemerality*, (<https://www.platformspace.net/home/mapping-ephemerality>) referring to scholarship on ephemeral architecture such as Ash Amin and Nigel Thrift, *Cities: Reimagining the Urban* (New York: Wiley, 2002); Swati Chattopadhyay, *Unlearning the City: Infrastructure in a New Optical Field* (Minneapolis: University of Minnesota Press, 2012); Amit Rai, *Jugaad Time: Ecologies of Everyday Hacking in India* (Durham: Duke University Press, 2019).
- 26 Gosha or a Gosha woman is described as someone who follows the Islamic law of concealing herself from the sight of men, except certain close relatives.
- 27 *Construction of sheds for Plague camps in Bangalore 1897-98* 26 of 97-98 1-5, Municipal Records in the Karnataka State Archives lists in detail the materials used to make the sheds that constitute mainly wood rafters and reapers (for pitched roof), corrugated iron sheet roof, washers and screws Bamboo tatty [sic] walls etc.
- 28 Batta roughly translates to 'bribe' or monetary incentive or tip.

REFERENCES

- "Address of the Dewan of Mysore to the Dasara Representative Assembly at Mysore on Tuesday the 17th October 1899, 1914." In *Addresses of the Dewans of Mysore to the Dasara Representative Assembly from 1881 to 1899*, Vol. 1. Bangalore: Government Press.
- Amin, A. and Thrift, N., 2002. *Cities: Reimagining the Urban*. New York: Wiley.
- Arnold, D. 1993. *Colonizing the Body: State Medicine and Epidemic Disease in Nineteenth Century India*. Berkeley and Los Angeles: University California Press.
- Bell, Duncan. 2010. "John Stuart Mill on Colonies." *Political Theory* 38, no. 1 (February): 34-64.
- Beverly, Eric Lewis. 2011. "Colonial Urbanism and South Asian Cities." *Social History* 36, no. 4 (December): 482-497.

The 'Unintended' City

- Beverley, E. L. 2015. *Hyderabad, British India, and the World: Muslim Networks and Minor Sovereignty, c. 1850–1950*. New York: Cambridge University Press.
- Cadwell, P. R. 1899. *Report on the outbreak of plague in the Civil and Military Station, Bangalore 1898-99*. Bangalore: Paragon Press.
- Chattopadhyay, Swati. 2005. *Representing Calcutta: Modernity, Nationalism and the Colonial Uncanny*. London and New York: Routledge.
- Chattopadhyay, S. 2012. *Unlearning the city: Infrastructure in a New Optical Field*. Minneapolis and London: University of Minnesota Press.
- Chattopadhyay, S. 2020. "Mapping Ephemerality." *Platform*. Last modified August 1, 2020. <https://www.platformspace.net/home/mapping-ephemerality>.
- Desai, M. and J. Lang. 2012. *The Bungalow in Twentieth-Century India: the Cultural Expression of Changing Ways of Life and Aspirations in the Domestic Architecture of Colonial and Post-Colonial Society*. London and New York: Ashgate Publishing.
- Foucault, M. 1984. "Space, Knowledge and Power." In *The Foucault Reader*, edited by Paul Rainbow, 239-256. New York: Pantheon Books.
- Glover, W.J. 2007. *Making Lahore Modern: Constructing and Imagining a Colonial City*. Minneapolis: University of Minnesota Press.
- Hazareesingh, S. 2007. *The Colonial City and the Challenge of Modernity: Urban Hegemonies and Civic Contestations in Bombay City (1900-1925)*. Hyderabad: Orient Longman.
- Hosagrahar, J. 2012. *Indigenous Modernities: Negotiating Architecture and Urbanism*. London and New York: Routledge.
- Karnataka State Archives. *Construction of Sheds for Plague Camps in Bangalore, 1897-98*. No. 26 of 97-98, 1-5. Municipal Records of the Karnataka State Archives.
- Kidambi, Prashant. 2007. *The Making of an Indian Metropolis: Colonial Governance and Public Culture in Bombay, 1890-1920*. Hampshire: Ashgate Publishing.
- King, Anthony D. 2006. "Postcolonial Cities, Postcolonial Critiques." In *Negotiating Urban Conflicts*, 15.
- Li, T. M. 2007. *The Will to Improve: Governmentality, Development, and the Practice of Politics*. Durham and London: Duke University Press.
- Lefebvre, H. 1991. *The Production of Space*. Translated by Donald Nicholson Smith. Oxford: Basil Blackwell.
- Legg, S. 2008. *Spaces of Colonialism: Delhi's Urban Governmentalities*. Malden, Oxford, and Victoria: John Wiley & Sons.
- Legg, Stephen. 2012. "Stimulation, Segregation, and Scandal: Geographies of Prostitution Regulation in British India, between Registration (1888) and Suppression (1923)." *Modern Asian Studies* 46, no. 6 (November): 1459-1505.
- Nair, Janaki. 2002. "Past Perfect: Architecture and Public Life in Bangalore," *The Journal of Asian Studies* 61, no. 4 (November): 1205-1236.
- Nair, J. 2005. *The Promise of the Metropolis: Bangalore's Twentieth Century*. New Delhi: Oxford University Press.
- Nair, J. 2009. "Beyond Nationalism: Modernity, Governance and a New Urban History for India," *Urban History* 36, no. 2 (August) 327-341.
- Nair, J. 2011. *Mysore Modern: Rethinking the Region Under Princely Rule*. Minneapolis and London: University of Minnesota Press.
- Nair, J. 2017. "Battles for Bangalore: Reterritorialising the City," SEPHIS papers. Bangalore: Centre for the Study of Culture and Society.
- Nandy, Ashis. 1998. "Introduction: Indian Popular Cinema as a Slum's Eye View of Politics." In *The Secret Politics of our Desires: Innocence, Culpability, and Indian Popular Cinema*, 1-18. London: Zed Books.
- Narasimmiyengar, V. N. 1893. *Census of India 1891 Mysore*. Provincial Superintendent of Census Operations in Mysore. Bangalore: Government Central Printing Office.
- Prakash, Gyan. 2002. "The Urban Turn." *Sarai Reader* 2, no. 7: 2-7.
- Proceedings. 1913. *The Proceedings of the Second All-India Sanitary Conference 1913 held at Madras, November 11th to 16th, 1912*, Vol. 11, Hygiene. Simla: Government Central Branch Press.
- Rai, A. S. 2019. *Jugaad time: Ecologies of Everyday Hacking in India*. Durham and London: Duke University Press.
- Ranganathan, Malini. 2018. "Rule by Difference: Empire, Liberalism, and the Legacies of Urban 'Improvement.'" *Environment and Planning A: Economy and Space* 50, no. 7 (October): 1386–1406.
- Rajnarayan, C. 1998. *Imperial Power and Popular Politics: Class, Resistance and the State in India, 1850-1950*. NY: Cambridge University Press.
- Rice, L. 1897. *Mysore: A Gazetteer compiled for the Government* (Revised Edition), Vol. II. London: Archbald Constable and Company.
- Ronald, R. 1923. *Memoirs with A Full Account of the Great Malaria Problem and Its Solution*. London: John Murray, Albermale Street.
- Stephens, J. H. 1914. *Plague-Proof Town Planning in Bangalore, South India*. Madras: Methodist Publishing House.
- Imperial Legislative Council of India. *The Epidemic Diseases Act 1897*. Act no. 3, February 4, 1897.
- Thompson, R.A. 1920. *Campbells Dictionary of Mysore and Bangalore*. Bangalore: Messrs Campbell and Sons.
- Thyagaraja, V. R. A. 1911. *Census of India, Volume XXI Mysore Part I - Report Superintendent of Census Operations, Mysore State*. Bangalore: Government Press.
- Viswanath, R. 2010. "Spiritual Slavery, Material Malaise: 'Untouchables' and Religious Neutrality in Colonial South India," *Historical Research* 83, no. 219 (December): 124-145.

TAPPING INTO URBAN RECYCLING FOR LOW-COST BUILDING ALTERNATIVES: Experimenting with Waste Cardboard Reuse in Architecture

Julio Diarte
Pennsylvania State University

Abstract: The work presented in this paper is part of a research that explores upcycling waste corrugated cardboard into building components. The research focuses on developing countries where there is a vast low-income population that needs housing but who find standard construction systems unaffordable. The research involves observational studies on the work of cardboard pickers in Paraguay seeking to understand the cycle of waste cardboard in the local context; development of digital tools to design building parts with waste cardboard and generate their fabrication instructions; hands-on work in an academic setting prototyping and testing building parts; and experimenting with the building system in the target context through workshops. This article summarizes several lessons learned during a workshop developed with a group of waste cardboard collectors and discusses the potential alternatives to the shortcomings.

Keywords: Waste cardboard architecture, construction workshop, low-cost building parts

INTRODUCTION

Although the use of brand-new cardboard products in architecture has received considerable attention from researchers and practitioners in the last three decades and especially after the emergence of Shigeru Ban's paper tube structures, there is very little formal research focused on the direct reuse of waste cardboard (Latka 2017; Salado 2011; Pohl 2009; Ayan 2009). The situation is more noticeable in developing countries where the recycling rate of post-consumer goods is meager, and materials like waste cardboard are highly underutilized (Silpa Kaza, Bhada-Tata, and Van Woerden 2018). The work presented in this paper is part of a research that explores material workflow and tooling development for reusing waste cardboard with minimal transformations into building parts (Diarte and Shaffer 2018). The research is focused on developing countries where there is a vast low-income population that needs housing—but for whom using standard construction systems is unaffordable—and the recycling rate of urban solid waste is very low—Paraguay has one of the lowest recycling rates of the region according to (IADB 2015).

The research involves different tasks. The most important are: a) observational studies on the work of cardboard pickers in Paraguay seeking to understand the cycle of waste cardboard in the local context; b) development of digital design tools to help designers to configure building parts with sheets of waste cardboard collected from the urban waste stream; c) hands-on work in an academic setting prototyping and testing building parts for a construction system with waste cardboard and wood; and d) experimenting with the building system in the target context through workshops.

The content of this paper is focused on the results of the work developed during a construction workshop held in Asuncion, Paraguay, in August 2019. In this workshop, the researcher worked with waste cardboard collectors that do not have a formal education in construction but have easy access to the material through different collection methods.

The workshop had two primary goals. The first was to test the ease of fabrication of the parts and ease of assembly of a prototype unit. The second goal was to test the transferability of the system and evaluate the perception of the participants. For this reason, the participants—guided by the researcher—worked for five days repurposing 1.2 tons of waste cardboard in the fabrication of wall and floor panels made of cardboard and plywood frames. At the end of the workshop, the participants used the panels to assemble a prototype building unit.

This article summarizes several lessons learned during the workshop and propose alternatives to the shortcomings. Some of the lessons were, for instance, the workshop confirmed that waste cardboard is easy to get, inexpensive, workable, and that teaching the technology to the participants is viable. Nevertheless, the experience also showed that the use of plywood, sophisticated joints, and the inexperience of the participants can have a significant impact on the cost and the building capacity. Despite the limitations, the lessons learned with the workshop certainly adds to the understanding of the different disciplines involved when developing new building systems together with a local population.

1. DESIGN CONCEPT OF THE PROTOTYPE UNIT

1.1. PANELIZED SYSTEM

The construction system presented here is a continuation of a first prototype presented by Diarte, Shaffer, and Obonyo in 2019. In that paper, the prototype unit was fabricated with panels made of waste corrugated cardboard logs and repurposed plywood frames. Its fabrication and assembly were tested in an academic environment. This paper presents a variation of that first prototype. The concepts adopted for the design of this second prototype unit (PU2) were: off-site prefabrication, modular/incremental construction, and adaptability of the construction system.

The PU2, as shown in figure 1, is a container-like structure composed of floor, wall, and ceiling panels. The three types of panels have similar dimensions (600 mm width, 2400 mm long, and 136-150 mm thick) but different fabrication details. The dimensions follow the standard size of plywood boards—1200 x 2400 mm—and they are easily found in the target context.

The PU2 designed for the workshop is 4200 mm long (or seven panels of 600 mm), 2400 mm wide (length of the standard panel), and 2700 mm height. Although it has the size of a standard room (10 m²) the PU2 does not intend to represent a house typology yet. For this workshop, the existing floor was used as a foundation, and two wood studs of section 2 x 5 inches were placed as a transition between the unit and the floor. "Lifting" the PU2 from the floor using these wood studs would also help to avoid potential humidity problems due to capillary rise.

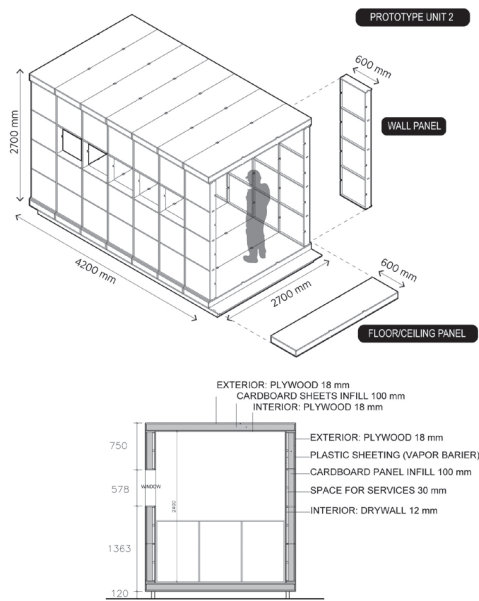


Figure 1: Prototype Unit (Author 2019)

1.2. FABRICATION OF THE PANELS

The panels have three main parts: frame, infill, and facing. The frame is fabricated with 18 mm plywood cut with conventional carpentry tools and/or a CNC router—if available—and then manually assembled using electric power tools and wood screws. Finger joints help to assure the connection between the pieces. The frame for the wall panel is composed of two vertical studs of 18 x 150 x 2400 mm each and four horizontal battens of 18 x 600 x 150 mm each that create four niches of 577 x 564 x 15 mm for the cardboard infill (figure 2a). For this experiment, all wall panels are the same; however, the design can have other configurations. The wood frame for the floor/ceiling is composed of two studs of 18 x 150 x 2400 mm each and two battens of 18 x 600 x 150 mm each. These frames did not have intermediate battens, but the assembly method is similar to the frames for the wall (figure 2c).

There are two versions for the infill of the panels: folded sheet tubes for the wall panels and flat sheets for the floor/ceiling panels. Figure 2b illustrates the components of the cardboard panel and the template used for fabricating the tubes. Eleven tubes of triangular section of dimensions 80 mm base and 80 mm height form each cardboard panel. The panel has a 577 x 564 mm facing sheet of cardboard on both sides. The flat sheets for the floor and ceiling panels do not need

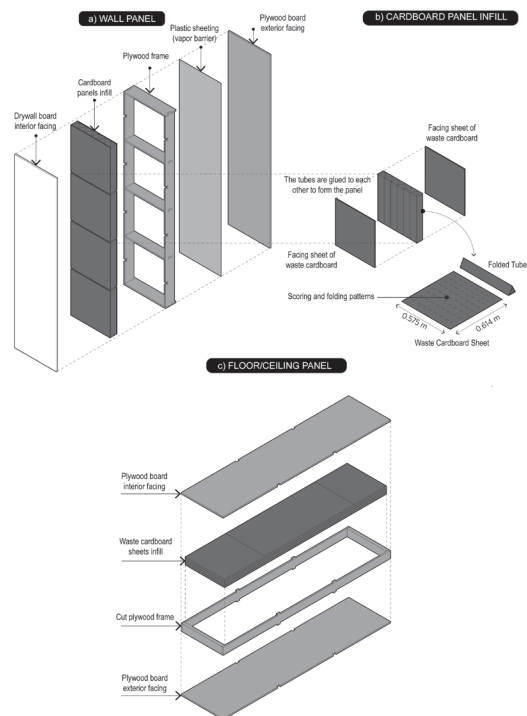


Figure 2: Main Components of the Panels (Author 2019)

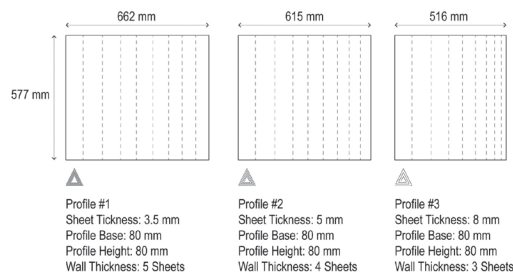


Figure 3: Waste Cardboard Sheet Templates (Author 2019)

templates and are layered one on top of each other inside the frame. This method allows the possibility of using sheets that are too small or too big for the tubes, increasing the reuse rate of the material. The exterior facing of the walls, for this prototype, is made of plywood boards of 18 mm on the exterior and 12 mm thick drywall boards on the interior with an additional plastic film on the exterior side that acts as a vapor barrier. Figure 2 illustrates each component of the panels.

1.3. PARAMETRIC DESIGN TOOLS

The folded sheet tubes for the wall panels are fabricated following the instructions provided by the parametric design tool presented in (Diarte, Vazquez, and Shaffer 2019a, 2019b). As stated in these papers, the tool facilitates the design of folded cardboard elements—in this case, triangular profile tubes—with sheets of different sizes and thicknesses. The tool receives two sets of data, the dimensions of the triangular profiles and the dimension of the sheets of waste cardboard. With this information, the tool generates different triangular profiles and calculates the best match with the available sheets of waste cardboard. Then, the tool visualizes the results showing the waste generated. Finally, the tool generates the instructions—templates that can be printed on paper or translated to paperboard or plywood—for cutting and scoring using hand tools. For this project, the parametric design tool was used to determine the cutting templates for three types of sheets of thicknesses 3.5 mm, 5 mm, and 8 mm. Figure 3 below illustrates the templates where the continuous lines represent cut lines and the dashed lines scoring lines.

2. ORGANIZATION OF THE WORKSHOP

The workshop had two primary goals. The first goal was to test the buildability of the prototype unit and the second goal to test the transferability of the system to local participants. Table 1 shows the workshop assessment framework prepared to organize the event. The table details how each goal was evaluated and documented.

Regarding the first goal, the focus was oriented in assessing how easy or difficult it was to fabricate the building parts and determine how adaptable is the system to the local situation. The task was subdivided into two parts: material collection and fabrication. The material collection consisted of obtaining the required supplies for the building, principally waste corrugated cardboard, plywood, and the necessary tools and fasteners. The variables measured to assess this task were cost, material supply time, and storage space needed.

To assess the buildability of the unit, we analyzed the capacities needed to execute each step of the workflow. Examples of questions this study sought to answer were:

- What type of equipment and tools are needed, and what are the specific requirements in terms of infrastructure?
- How many people are required to complete the workflow?
- What skills are they required to have?
- How much time is required to train the participants to use the space, equipment, and tools?
- How much space is needed to set up all the components of the workflow safely?

To evaluate if the system is easy to transfer or not, the experiment looked at the next elements:

- How easy or difficult it was for the participants to understand the fabrication instructions
- How much time was invested on each part of the workflow to fabricate and assemble the panels
- What was the quality of the outcome (e.g., the accuracy of the parts, joints, weight, and steadiness of the panels)

At the end of the workshop, the participants answered a questionnaire previously prepared to try to collect information to answer these questions. The questionnaire's goal was to document the participant's experience during the week and inquire how likely are they to use part of what they learned.

2.1. VALUE OF FULL-SCALE MOCK-UPS

This study is based on the fabrication of a full-scale prototype structure or mock-up. The use of full-scale mock-ups in architecture and engineering facilitates several aspects of the process of testing the construction of buildings or part of them (Designing Buildings Wiki n.d.). It is an essential process for testing innovative applications of construction materials and building systems. This process allows researchers/designers to identify potential problems, limitations, or constraints. Mock-ups are also useful to get feedback from the participants about the proposed fabrication workflow and the technology itself.

Tapping into Urban Recycling for Low-cost Building Alternatives

Workflow Components→	Material Collection	Fabrication of Building Parts	Assembly of the Prototype Bay Structure
Sub-components	<ul style="list-style-type: none"> Material Collection (timber and waste cardboard) Waste Cardboard Sorting Waste Cardboard Documentation 	<ul style="list-style-type: none"> Design of Building Parts (floor and wall panels) Fabrication of Building Parts (floor and wall panels) 	<ul style="list-style-type: none"> Building Parts Transportation Building Parts Assembly Sheathing Installation
	↓	↓	↓
Goal →	To determine how feasible it is to get cardboard and how much of the cardboard collected is useful	To assess how easy it is to understand the fabrication process and its affordability	To evaluate the practicability of the assembly process and how many people are needed.
Assessment Procedure / Feature Evaluated →	<ul style="list-style-type: none"> Quantification of time spent collecting and documenting Quantification of the amount of material collected: How much was recovered and how much was discarded? 	<ul style="list-style-type: none"> Easy understanding of the fabrication instructions Use of material/waste Time spent in the fabrication Workforce Workspace Tools and hardware used Quality of the building parts (geometry, weight, shape accuracy) 	<ul style="list-style-type: none"> Easy understanding of the assembly instructions Easy of transportation Time spent in the assembly Quality of the assembly (accuracy of the joins, the steadiness of the structure)
Questions addressed →	<ul style="list-style-type: none"> How easy is it to get the waste cardboard? How much does it cost to get the material needed? Is waste cardboard low-cost? 	<ul style="list-style-type: none"> How much time takes to fabricate the building parts? How many people are needed for the fabrication? How easy is it to fabricate the parts? Can this be made with low-construction skills people? 	<ul style="list-style-type: none"> How much time does it take to assemble the unit? How easy is it to assemble the unit?
Outcome / Deliverable →	Receipts detailing the amount of material provided	Prototype unit structure, a survey completed by the participants of the construction workshop evaluating each one of the steps mentioned above, notes, and visual documentation of the construction process.	
Participants →	Local NGO	<ul style="list-style-type: none"> Four participants (collectors of waste cardboard with little or no experience with construction) Two assistants (student from the architecture school) 	
Data Collection Procedure →	On-site Survey	<ul style="list-style-type: none"> Audio, video, notes, and photography Survey at the end of each part 	

Table 1: Workshop Assessment Framework

Previous research done on cardboard architecture showed that this type of approach allows the parties involved to test the manufacture of the components and the assembly process. An example of this is the project for the Westboro School in Essex, the UK, designed by Cottrell & Vermeulen and Buro Happold Consulting Engineers in 2004 (Cripps 2004). The school building's mock-up was one-sixth part of the whole building, and the research team confirmed the importance of the mock-up to "save money and time." In general, researchers in the area of residential building construction value full-scale mock-up testing because this provides information about usefulness, safety, and quality (Memari et al. 2014, 28).

2.2. LIMITATIONS OF THE WORKSHOP

Although the outcomes of this workshop are beneficial for further improvement of the building system, the

results cannot be used to draw statistical analysis. This is because of the limited scope of the experiment and the reduced number of participants. Another factor that cannot be assessed here is the livability of the prototype structure or how the building responds over time. Although the full-scale mock-up shows the real scale of the building and the participants can express their impressions about it, it is not possible to evaluate with precision factors such as comfort, safety, functionality, stability against the elements, and privacy in the long-term.

2.3. THE PARTICIPANTS

The goal of the project is to design a housing system addressed for people who cannot afford to build their houses using standard construction materials—e.g., timber, masonry, steel, and concrete—but have direct access to waste corrugated cardboard. Consequently, the main criteria for including participants were the next.

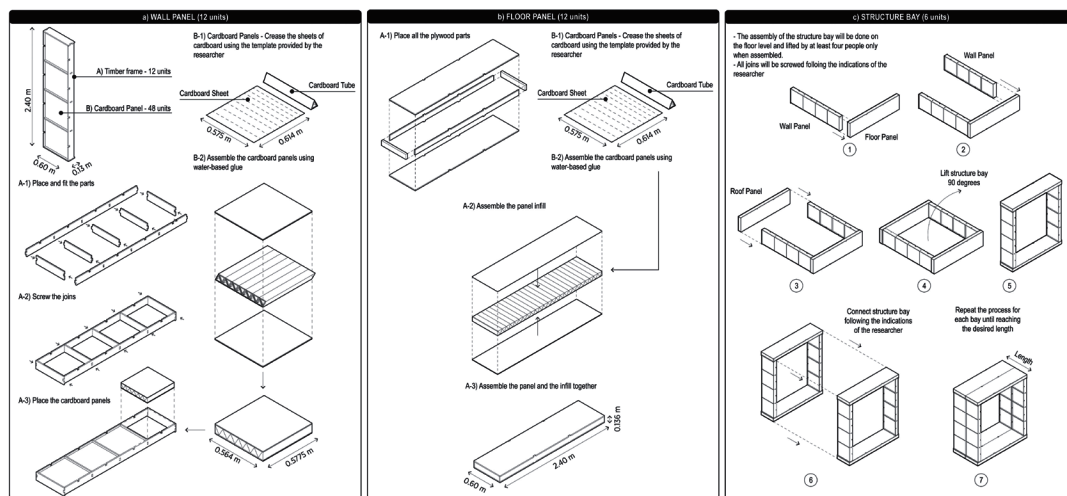


Figure 4: Fabrication Instructions (Author 2019)

Firstly, the participants should have formal or informal experience as collectors of waste cardboard, so they can learn about the opportunities for using this material. Secondly, the participants should have little or no experience at all in construction, so the researcher could test how easy it is to understand the system.

2.4. FABRICATION INSTRUCTIONS AND LIVE DEMOS

Figure 4 shows the instructions handed to the participants. The printed fabrication instructions summarize the fabrication of wall, floor, and ceiling panels. The instructions include step-by-step instructions for the fabrication of the parts and the assembly of the structure bay and the consequent assembly of the whole unit. These instructions are meant to guide the participants in the process; however, live demos showing each step of the process are also necessary.

3. RESULTS

3.1. THE WORKSHOP'S LAYOUT

One of the factors that this experiment sought to evaluate was to identify the infrastructure needed to operate the fabrication workflow. In this regard, the workshop was held at the Center for Research, Development, and Innovation (CIDI) located at the School of Architecture, Design, and Arts at the National University of Asuncion (FADA-UNA). The workshop occupied a multifunctional area inside the CIDI destined for exhibitions, lectures, and workshops that offered easy access for both participants and suppliers.

Figure 5 shows the spatial organization of the workshop emphasizing the following: a) woodworking area (25 m²); b) area for the fabrication of cardboard

parts and assembly (70 m².); c) lectures and lunch (20 m²); d) plywood and drywall storage area (20 m²); and e) discarded cardboard storage area (10 m²). An additional area used was located at the Industrial Design's woodshop at FADA-UNA where the shop's staff precut part of the wood frames. Overall, without considering the area of the woodshop, the workshop occupied around 145 m². of space. Besides having enough space and the conventional infrastructure needed to operate power tools, no other special equipment or infrastructure was required to develop the work.

3.2. MATERIALS USED

The local NGO *ProCicla* provided 1.2 tons of sheets of waste cardboard in two batches in two different days a week before the workshop. The first batch of 0.55 tons on August 5 and then 0.65 tons on August 8. The material came from a clothing store, and it was stored at the location of the workshop occupying around 30 m². Around 5% of the material was discarded because it was torn or contaminated with food or liquids. No documentation of individual cardboard sheets was made due to the amount of time this was going to take. What was not discarded was roughly classified by size, but the elevated level of variability of the sheets made it challenging to assess with precision the quantity and size of sheets. Later in the paper, it will be explained how the sheets were selected to fabricate the building parts. Other materials used for the construction of the unit included wood (plywood boards and rafters), drywall, plastic sheets for the vapor barrier, and fasteners.

Table 2 shows the summary statistics for materials used in the construction of the unit. What stands out in the table is the low-weight and the low-cost of the

Tapping into Urban Recycling for Low-cost Building Alternatives

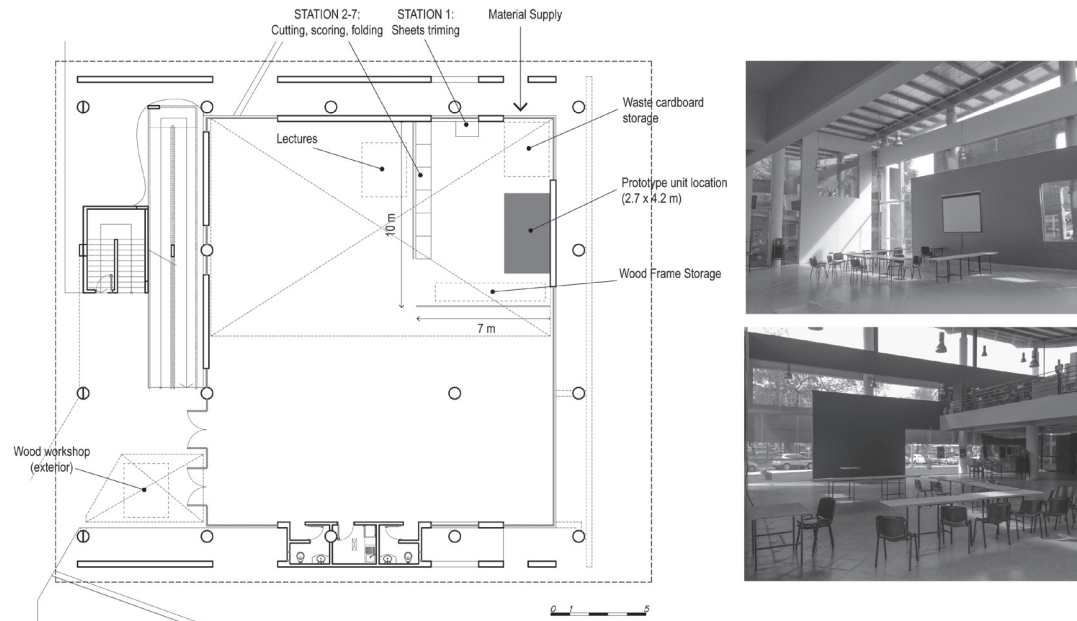


Figure 5: Layout of the workshop and views of the interior space at the CIDI. (Author 2019)

cardboard sheets (15% of the total weight and 8% of the total cost) compared to the volume occupied by this material (almost 60% of the total volume is occupied by cardboard). This feature of cardboard has a positive influence on the total weight and the total cost of materials. However, the impact of timber on the total weight and total cost of materials is something to be considered carefully (65.62% of the total weight and 78% of the total cost of materials). This impact can also be positive if we think it could increase the stability of the structure against potential horizontal forces (wind and earthquakes). On the other hand, the impact on the cost forces to develop strategies to reduce the amount of timber or replace it with something less expensive.

Table 3 shows the budget composition of the unit, including items such as hardware, fasteners, tools, labor, transportation, and the materials mentioned above. This budget does not include municipal permit costs and designer's honoraria, foundation, doors,

windows, finishing, or any electrical, heating, cooling, and ventilation installations. Although the analysis of this budget may be somewhat limited because it does not include these items, it is useful to observe the impact of each item. In this sense, the most significant information observed in this figure is, again, the high impact of materials in the budget, where timber is the most expensive item. Transportation costs were minimal, mostly because the fabrication and assembly were done at the same location. The incentives paid to the participants were equivalent to the minimum wage established by law in Paraguay, which also applies to low-ranking workers in local construction companies. The impact of labor cost is within the usual percentage (25-30%). Another interesting aspect found in the analysis of the cost of the unit built in this workshop is revealed when the cost per m² of the unit is compared to the one of standard housing construction in the local context. The cost of this unit was \$183 per m² and the

Material		By Volume (m3)	%	By Weight (tons)	%	By Cost (US\$)	%
Timber	Plywood	2.55	38.39%	0.54	62.12%	\$1,005.56	74%
	Studs	0.03	0.38%	0.03	3.50%	\$59.55	4%
Cardboard		3.82	57.59%	0.13	15.01%	\$111.11	8%
Drywall		0.24	3.64%	0.17	19.14%	\$82.49	6%
Plastic Sheet		0.00	0%	0.00	0.23%	\$7.58	1%
Fasteners		0.00	0%	0.00	0%	\$99.84	7%
Totals		6.64 m3		0.86 tons		\$1,366.12	

Table 2: Summary of materials used in the construction of the unit

cost of an equivalent construction made with traditional building materials, according to current reports on building construction in Asuncion, is around \$146 per m². (Mandu'a 2019). The main reason the cost of the unit is higher is probably due to the high cost of the timber. Nevertheless, several other factors can be used to compare both systems that are not being considered here, such as the environmental impact in the long term, that could factor in as an advantage for using waste cardboard and wood frames.

Item	Cost	%
Hardware, Fasteners & Tools	\$176.37	9.53%
Labor	\$475.84	25.72%
Materials	\$1,192.21	64.45%
Transportation	\$5.35	0.29%
	\$1,849.77	

Table 3: Budget Composition of the Unit

3.3. PARTICIPANTS

The recruitment process was done through direct contact with people related to the collection of urban waste in the metropolitan area of Asuncion. *Soluciones Ecologicas SRL*, a private company in Asuncion dedicated to collection and waste management, facilitated the contact with a group of collectors with whom they work. Four people, two females and two males, participated in the workshop for five consecutive days. The educational attainment of the participants was high school graduate or equivalent. Of the four participants, one had experience working for two years in a construction company as laborer assisting in the construction of masonry walls. The other two had informal experience on self-construction of their own house – masonry walls and metal sheet roofing. Although all of them had informal experience working in the collection of waste cardboard and other recyclables, none of them had ever used cardboard as a construction material. Table 4 summarizes the information of the participants.

Participant #	Gender	Age Range	Formal Experience in Construction	Informal Experience in Construction
Participant #1	Female	40-45	No	Yes: Self-construction of own house
Participant #2	Male	45-50	No	Yes: Self-construction of own house
Participant #3	Female	20-25	No	No
Participant #4	Male	50-55	Yes: 2 years working as a laborer in a building company	Yes: Self-construction of own house

Table 4: Participant's Basic Information

3.4. FABRICATION AND ASSEMBLY WORKFLOW

The diagram in figure 6 shows the fabrication workflow of the workshop. The workflow consisted of two parts: the fabrication of cardboard panels and the fabrication of wood frames. Each part occupied a different location; the cardboard panels were fabricated in the space arranged at the CIDI, and the wood frames were cut at the woodshop. The researcher guided the participants in the fabrication of the cardboard panels and the assembly of the panels. The workshop took five days working from 9 am to 5 pm approximately.

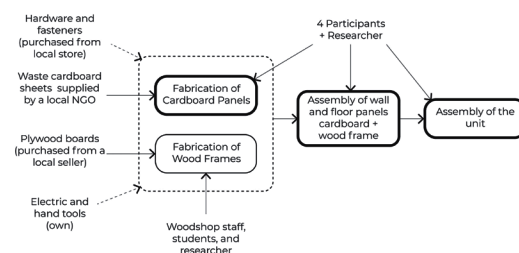


Figure 6: Fabrication Workflow Diagram (Author 2019)

On the first day of the workshop, after introducing the participants to the goals of the research, the researcher presented the fabrication instructions and handed printed copies in the form of booklets to the participants so they could consult them whenever they. During the introduction, the researcher explained the workflow, showing the working stations, and the available tools. The participants worked only in the fabrication of cardboard panels and the assembly of the panels (steps 7-a to 7-h in Fig. 7 and steps 8-a to 8-d in Fig. 8). Since the participants did not have any experience cutting wood and to avoid accidents, the researcher, together with the woodshop staff and interns, pre-cut the timber frames before the workshop.

Fabrication of Cardboard Panels

Steps 7-a to 7-h in figure 7 illustrates the fabrication process of cardboard panels. The process started with selecting the sheets that were not torn or contaminated

Tapping into Urban Recycling for Low-cost Building Alternatives

with food or liquids and having the minimum required dimension for the tubes and facing (step 7-a). In step 7-b, the selected sheets were trimmed to the indicated dimensions. Next, in step 7-c, the participants scored the sheets following a pre-cut template. For this task, the participants used a conventional knife and wood templates made of $\frac{1}{4}$ inches plywood. In Step 7-d, the participants folded the sheets manually to form the tube adding water-based adhesive to hold it.

Step 7-e consisted of spraying a solution of Boron and water (1:10) for fungal and insect attack protection treatment. Boron is a chemical component commonly used in agriculture that has insecticidal and fungicidal properties. According to previous research by Kaminski et al. published in 2016, it is the most convenient chemical used to treat bamboo. The researcher decided to replicate the use of this chemical for the preservation of cardboard, considering certain resemblance of both materials—cardboard is made of fibrous and natural materials similar to bamboo.

In step 7-f, the participants assembled the cardboard panels. Each panel used eleven cardboard tubes and two facing sheets that were glued together using water-based adhesive. The team fabricated a total of 561 cardboard tubes and cut 102 facing sheets. Both the tubes and the facing sheets were employed to fabricate 51 cardboard panels of dimensions 565 x 577 x 100 mm. Figure 7-g shows a participant trimming the cardboard panel using a handsaw to correct some inconsistencies in its dimensions. It also shows two

participants placing the cardboard panels inside the wood frame. The cardboard panels were placed applying manual pressure and did not need any adhesive.

Assembly of Building Parts

Figure 8-a to 8-d shows the process of assembling the building parts. Figure 8-a shows the placement of two studs on the floor. Figure 8-b shows the procedure for assembling the floor panels. The top image of figure 8-b shows the uncovered and empty floor panel on which the sheets of cardboard that were not used for the tubes were placed. The bottom image of the same figure shows all floor panels placed on top of the studs. Each panel was joined to the studs and to each other by using conventional screws. Images on 8-c show the participants placing the plastic sheeting for vapor barrier protection. The bottom image shows a wall panel where one of the niches will be used for placing a window. Figure 8-d showed in the top image when the participants were placing the ceiling panel, and the bottom view is a general view of PU2 on the last day of the workshop, when the team managed to assemble the unit partially.



Figure 7: Fabrication Process for the Cardboard Panels (Author 2019)



Figure 8: Assembly Process of Floor, Wall, and Ceiling Panels (Author 2019)

DISCUSSION

What were the lessons learned from this workshop?

The first goal was to analyze how feasible it is to get enough waste cardboard to build the PU2 and how much of the cardboard collected is used for the project. The answer to the first part is affirmative; getting the material was relatively uncomplicated. Regarding the second part, the project used around 80% of the 1.2 tons supplied by ProCicla, and the remaining 20% were sent back for free to recycling—the leftover could have even been resold to recycling companies for the same price they were purchased.

However, there are a few aspects to consider that could have a significant impact on the project. The first consideration regards who provides the material. In this sense, the study found that there are three ways of obtaining waste cardboard in the context of Asuncion and the metropolitan area: a) from self-employed cardboard collectors; b) from private companies or NGO's dedicated to waste management, including the collection of recyclables; or c) directly from cardboard factories.

Initially, for this workshop, the plan was that self-employed collectors would provide the waste cardboard needed. Nevertheless, this option was discarded because the collectors could not get enough material in such a short time—just one week before the workshop—and they could not guarantee the quality of the material either because the material they usually get comes directly from the streets and dumpsters. To make this possible, the period for collection and selection must be longer, and this was not possible for this workshop.

In the second option, which was the one used for this workshop, the time was not inconvenient; and the quality was acceptable, because the supplier collects waste cardboard sheets weekly from large clothing stores and commercial centers. In this kind of place, the material is handled generally in interior spaces, and it is not exposed to the elements, assuring a relatively decent quality that facilitates its reuse—e.g., the sheets are not wet and torn. The cost of the waste cardboard provided by the NGO was the same as that of the collectors—around 8 cents of a dollar per kilogram.

The third option, getting the material from cardboard factories, was discarded because although these companies could have provided high-quality waste cardboard at the same price as the other suppliers, the material represents another kind of sample. Waste cardboard from factories is usually leftover from template cuts that are small in size.

The experience of this workshop suggests that, although the material is inexpensive and relatively easy to get, it is critical to evaluate who will provide the material and how to manage this component. The characteristics of the material—e.g., quality, quantity,

and size—vary depending on who is the provider. On the other hand, storing and handling waste cardboard sheets is an unclean task that requires protective equipment and clothing, and a large and well-ventilated covered area to avoid working in a polluted space.

The second goal of the workshop was to assess how easy it is to understand the fabrication process and test how affordable the system is in the local context. To evaluate how easy it is to understand the process, it is essential to consider separately the two phases of the fabrication workflow shown previously in figure 5. For the first phase fabrication of cardboard panels, contrary to the expectations, the participants did not pay as much attention to the printed handouts with visual instructions as to the live demos. According to what they expressed during the interview at the end of the workshop, they did not use the printed handouts because they are not used to following graphic instructions.

The live demos, on the other hand, were easier to follow because they could see everything in full-scale and ask questions of the instructor if needed. This situation is understandable considering the subjects did not have experience participating in this kind of activity; however, it raises the question the best approach and the appropriate supporting materials for teaching people how to build using this system.

In general, the fabrication of the cardboard panels was an uncomplicated task for the participants, and they confirmed this during the interview. Some of the factors they mentioned as positive during the process of fabricating the cardboard panels were, for instance, the workability of cardboard (e.g., easy to handle and lightweight), the familiarity with the tools (e.g., knife, wood templates, adhesive, etc.), and the easiness of the step-by-step process. The participant manifested their surprise regarding the potential of the material and showed interest in other possible applications.

Regarding the second phase, fabrication of the wood frames, it is essential to highlight that the participants did not have contact with this process for the reasons mentioned earlier in this paper. The instructor and woodshop assistants managed the process of cutting the parts for the frames. In order to enable the participants to operate the tools, it is necessary to implement a more extended training period which was not possible for this workshop. The participants did assemble the wood frames, though, and the process was not as easy as expected. The main issue was, according to them, the “complicated design of the parts” with different pieces and the many joints.

Regarding the affordability of the system, the workshop has shown that timber has a substantial impact on the total cost of the prototype (78% of the total cost of materials). This factor will force us to

Tapping into Urban Recycling for Low-cost Building Alternatives

explore alternative ways to reduce the amount of timber and increase the amount of waste cardboard in the design of the prototype. A current study is looking into the design of the wall panels and testing the mechanical performance of waste cardboard panels of different thicknesses to decrease the quantity and thickness of the plywood elements.

Another goal of the workshop was to evaluate the practicability of the assembly process and the number of people needed for this task. Overall, learning how to assemble the wall and floor panels requires training and practice to achieve quality. Although the workshop presented an excellent opportunity to test this, and the participants did learn how to do it, the available time did not allow them to finish the assembly of the whole PU2 and thus to reach the optimal quality of finishes. With respect to the number of people needed for the task, it was indeed possible to build this unit with four participants; however, the number of people needed to scale up the production is still uncertain, and cannot be determined with the results of this workshop.

CONCLUSION

The purpose of the construction workshop presented in this paper was to test the feasibility of the panelized building system using sheets of waste cardboard and plywood mainly. In this paper, the author presented the design concept of a prototype unit, describing the

process for fabricating its parts, the methodologies planned to develop the construction workshop, and discussed the main lessons learned from the experience. The incorporation of local collectors of waste cardboard as participants of the workshop allowed the researcher to test the system working with potential users of the technology. Overall, the workshop has shown the feasibility of the fabrication of panels using sheets of waste cardboard and simple tools, and the usefulness of digital design tools to provide the cutting/scoring instructions for the participants. The relative feasibility of the assembly system and the substantial impact of the use of plywood in the total cost were additional factors analyzed during this experiment. Further research is being developed to decrease the amount of timber and increase the use of waste cardboard, as well as to simplify the fabrication instructions.

ACKNOWLEDGMENTS

The author wants to express his gratitude to the Stuckeman Center for Design Computing of the Stuckeman School at Penn State University for the financial support, to the CIDI for the support in the organization and development of the workshop, and to *Soluciones Ecologicas SRL* and *ProCicla* for their valuable support and input.

REFERENCES

- Ayan, Özlem. 2009. "Cardboard in Architectural Technology and Structural Engineering." *ETH Zurich*. <https://doi.org/http://dx.doi.org/10.3929/ethz-a-006080626>.
- Cripps, Andrew. 2004. "Cardboard as a Construction Material: A Case Study." *Building Research & Information* 32 (3): 207–19.
- Designing Buildings Wiki. n.d. "Samples and Mock-Ups for Construction." Accessed April 10, 2019. https://www.designingbuildings.co.uk/wiki/Samples_and_mock-ups_for_construction.
- Diarte, Julio, and Marcus Shaffer. 2018. "Urban Recycling Intervention: Devising Low-Cost Tools for Transforming Old Corrugated Cardboard into Building Elements and Construction Materials." In *10th International Conference on the Environmental and Technical Implications of Construction with Alternative Materials*, edited by Pentti Lahtinen and Ville Raasakka, 362–66. Tampere: ISCOWA The International Society for the Environmental and Technical Implications of Construction with Alternative Materials.
- Diarte, Julio, Marcus Shaffer, and Esther Obonyo. 2019. "Developing a Panelized Building System for Low-Cost Housing Using Waste Cardboard and Repurposed Wood." In *Proceedings of 18th International Conference on Non-Conventional Materials and Technologies – IC NOCMAT 2019 Nairobi, Kenya, 2019*, edited by Normando Perazzo Barboza, 155–66. Nairobi: Universidade Federal de Paraíba Brazil.
- Diarte, Julio, Elena Vazquez, and Marcus Shaffer. 2019a. "Tooling Cardboard for Smart Reuse: A Digital and Analog Workflow for Upcycling Waste Corrugated Cardboard as a Building Material." In *Computer-Aided Architectural Design. "Hello, Culture,"* edited by Ji-Hyun Lee, 384–98. Singapore: Springer Singapore. https://doi.org/https://doi.org/10.1007/978-981-13-8410-3_27.
- Diarte, Julio, Elena Vazquez, and Marcus Shaffer. 2019b. "Tooling Cardboard for Smart Reuse: Testing a Parametric Tool for Adapting Waste Corrugated Cardboard to Fabricate Acoustic Panels and Concrete Formwork." In *Architecture in the Age of the 4th Industrial Revolution - Proceedings of the 37th ECAADe and 23rd SIGraDi Conference*, edited by J Sousa, J Xavier, and G Castro Henriques, 2:769–78. Porto: eCAADe, SIGraDi, FAUP. http://papers.cumincad.org/cgi-bin/works/paper/ecaadesigradi2019_197.
- IADB. 2015. "Solid Waste Management in Latin America and the Caribbean." *Inter-American Development Bank*. <https://publications.iadb.org/handle/11319/7177#sthash.7bODjAHq.dpuf>.
- Kaminski, Sebastian, Andrew Laurence, David Trujillo, and Charlotte King. 2016. "Structural Use of Bamboo. Part 2: Durability and Preservation." *The Structural Engineer: Journal of the Institution of Structural Engineer* 94 (10): 38–43.

Latka, Jerzy F. 2017. "Paper in Architecture: Research by Design, Engineering, and Prototyping." The Delft University of Technology. <https://doi.org/10.7480/abe.2017.19>.

Mandu'a, Revista. 2019. "Casa Mandu'a - Vivienda Modelo 1." *Revista Mandu'a*, 2019. https://issuu.com/a.arza/docs/mandua_digital_octubre438.

Memari, Ali M., Patrick H. Huelman, Lisa D. Iulo, Joseph Laquatra, Carlos Martin, Andrew McCoy, Isabelina Nahmens, and Tom Williamson. 2014. "Residential Building Construction: State-of-the-Art Review." *Journal of Architectural Engineering* 20 (4): B4014005. [https://doi.org/10.1061/\(asce\)ae.1943-5568.0000157](https://doi.org/10.1061/(asce)ae.1943-5568.0000157).

Pohl, Almut. 2009. "Strengthened Corrugated Paper Honeycomb for Application in Structural Elements." *ETH Zurich*. <https://doi.org/http://dx.doi.org/10.3929/ethz-a-006060041>.

Salado, Gerusa de Cássia. 2011. "Painel de Vedação Vertical de Tubos de Papelão: Estudo, Proposta e Análise de Desempenho." Ph.D. Thesis, Universidade de Sao Paulo.

Silpa Kaza, Lisa Yao, Perinaz Bhada-Tata, and Frank Van Woerden. 2018. *What a Waste 2.0 A Global Snapshot of Solid Waste Management to 2050*. 1st ed. Washington DC: International Bank for Reconstruction and Development / The World Bank. <https://doi.org/10.1596/978-1-4648-1329-0>.

WEAVING *FABRICA* AND *RATIOCINATIO*: An Inquiry into the Knowledge of Architecture in Vitruvian Theory

Hayri Dortdivanlioglu
Georgia Institute of Technology

Abstract: This study focuses on *fabrica* and *ratiocinatio*, two fundamental components of architecture, forming the foundational framework of Vitruvian theory. Despite their significance, the Vitruvian text neither gives clear definitions of these terms nor explains their role in architecture. The extensive literature on *fabrica* and *ratiocinatio* has produced various interpretations based on the doctrine of duality between the two concepts. Scholars view *fabrica* as the activity of performing a craft, while they interpret *ratiocinatio* as reasoning and argumentation in rhetoric. Their comparison between *fabrica* and *ratiocinatio* reveals a fundamental distinction where the former is the activity of manual labor, and the latter is the activity of intellectual labor. This distinction becomes significant for Vitruvian literature to the extent that they define both concepts in oppositions of practice versus theory.

Building upon the existing literature, this study questions the relationship between *fabrica* and *ratiocinatio* in the Vitruvian theory of architecture. Rather than focusing on the opposition between the two Vitruvian concepts, it seeks interactions between *fabrica* and *ratiocinatio*. To that end, this study not only offers a close reading of Vitruvian passages but also analyzes the etymology and use of these two concepts in other fields, including *technē* and rhetoric, from which *fabrica* and *ratiocinatio* have originated. It argues that while the origins of these concepts are opposed to each other as concerning purely practical and theoretical activities of architects, this paper shows that Vitruvius redefines them within his architectural theory. First, Vitruvius defines *fabrica* with *meditatio* to show that it is not only a manual but also a mental activity. Secondly, he extends the use of *ratiocinatio* from rhetoric into architecture by defining it as an activity that provides persuasion and coherence in work through both demonstrating and making. By doing so, Vitruvius sets *fabrica* and *ratiocinatio* in action together. They work interdependently. In the last part, this study will examine how *fabrica* and *ratiocinatio* interact with each other and work in and through drawing which is an activity of both hands and mind.

Keywords: Vitruvius, architectural theory, *fabrica*, *ratiocinatio*, interwoven, drawing

INTRODUCTION

Vitruvius starts his famous treatise, *De Architectura*, by stating that the knowledge of architecture, which is “equipped with many branches of study and varied kinds of learning”, is born from *fabrica* and *ratiocinatio* (1.1.1). These two concepts form the foundational framework of Vitruvius’s theory of architecture. Understanding the role of *fabrica* and *ratiocinatio* in architect’s knowledge is therefore a key to unfolding the body of Vitruvian theory. This essay focusing on the interaction between *fabrica* and *ratiocinatio* is an initial study of broader research on the relationship between three main conceptual frameworks of Vitruvius’s theory of architecture. *Fabrica* and *ratiocinatio* form the first framework of his definition of architecture (1.1.1). The second framework is his six principles of design: *ordinatio*, *dispositio*, *eurythmia*, *symmetria*, *decor*, and *distributio* (1.2.1). The third framework is his famous triadic structure of *firmitas*, *utilitas*, and *venustas* (1.3.2). Vitruvius’s six principles interact under *fabrica* and *ratiocinatio*, and they lead the architecture towards his triadic structure. In the eighteenth

century, Berardo Galiani (1758), who produced an Italian translation of *De Architectura* with an extensive commentary, illustrated that *fabbricazione* (building), one of the three main components of the architecture, derives from both part of *fabrica* and *ratiocinatio* for which he uses *pratica* (practice) and *teorica* (theory) respectively (figure 1).² Galiani’s diagram shows that both *fabrica* and *ratiocinatio* are linked to a network of Vitruvian principles. The diagram’s network structure shows that Galiani implies reciprocity between these two concepts, but how do they work together? What is the role of *fabrica* and *ratiocinatio* in Vitruvian theory?

Despite their significance, the meaning of *fabrica* and *ratiocinatio* remains obscure for modern readers due to their textual and semantic problems. The promise of solving these problems resulted in a rich literature including numerous translations with heavy commentaries and literary studies on the meaning and role of *fabrica* and *ratiocinatio* in architecture, specifically in Vitruvian theory. These studies vary in approach, scope, and focus, but they mostly consider

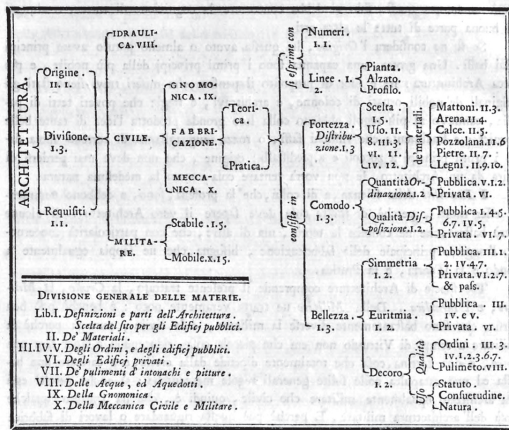


Figure 1: Galiani's diagram of Vitruvian concepts. (Galiani 1758, xv)

fabrica and *rationcinatio* in a duality of practice versus theory. One group of scholars, including Daniel Barbaro (1584), Carl Watzinger (1909), Louis Callebaut (2001), Edmond Frezouls (1985, 1989), and Pierre Gros (2006), considers *fabrica* as work (*opus*) and *rationcinatio* as the reflection, or discussion on the work carried out, i.e., *rationcinatio* always comes after the work is completed. Focusing on *rationcinatio* as a term originated in rhetoric, they link Vitruvian pair to another obscure rhetorical pair of *significatur* (work) and *significat* (explanation), which Vitruvius discusses next in the same chapter. According to Frezouls (1985), *rationcinatio* is the intellectual activity that analyzes the technical achievement of *fabrica*. He claims that lack of *rationcinatio* does not prevent architects from building well but from obtaining the authority through a reasoned explanation. Likewise, Watzinger asserts architects must not only build, but also make judgments about their buildings; they must not only be practical but also theoretically educated (1909, 203). While Watzinger suggests a balance between *fabrica* and *rationcinatio*, Barbaro (1584) and Gros (2006) argue that Vitruvius privileges latter over former. Barbaro claims that judging a work is the differentiating quality (*differentia specifica*) of architects (Williams, 2019, xvii).³

On the other hand, another group of scholars, including Claude Perrault (1673, 1674), Galiani (1758), and Jolles (1905), considers *fabrica* as practical knowledge and *rationcinatio* as theoretical knowledge. Galiani explains that the theory consists of knowing how to conceive the best distribution of a given space to form it with the most convenient materials. The practice then consists of knowing how to implement the already conceived idea in work (1758, xvi). Claiming that theory is the basis of practice, this group of scholars considers that *rationcinatio* precedes *fabrica* in Vitruvian theory.

To highlight this order, in his well-received abridgment, Perrault explains *ratiocinatio* before *fabrica*, even though in the original text the former appears before the latter (Perrault, 1674). In the English edition of his abridgement, he writes, “[t]he theory of architecture is that knowledge of this art which is acquired by study, travelling and discourse. The practice is that knowledge that is acquired by the actual building of great fabricks” (Perrault 1692, 24). Similar to Perrault’s view, Jolles (1905) considers *fabrica* as knowledge of the technique of craft and *ratiocinatio* as theoretical knowledge. Thus, a duality between *fabrica* and *ratiocinatio* dominates the interpretations of Vitruvian concepts.

This duality can also be observed in classical Greek philosophy associated with Vitruvius's *fabrica* and *ratiocinatio* (Frezouls 1989, 41). Scholars point out indeed that the Vitruvian pair of *fabrica* and *ratiocinatio* recalls classical Greek oppositions, such as the one between *technē* (craft, skill) and *epistēmē* (knowledge)⁵, or Aristotelian *ergon* (work) and *logos* (reason)⁵, or Plato's distinction of science as *praktikē* (the science of action) and *gnostikē* (the science of mere knowing)⁶. Furthermore, this duality appears in the fields that *fabrica* and *ratiocinatio* stem from, i.e., respectively, craft and rhetoric. Since Vitruvius writes *De Architectura* on the cusp of emerging Latin language in the early Roman Empire, there were not many Latin texts produced on art and architectural criticism in his time (Fitzpatrick 2017, 4). Consequently, Vitruvius adapts most of his concepts, including *fabrica* and *ratiocinatio*, from Greek and early Roman sources into his architectural theory (Fitzpatrick 2017; Rowland 2005). Vitruvius borrows *fabrica* from craft and *ratiocinatio* from rhetoric, thereby continuing the established duality. Indeed, ancient Greeks saw craft as a form of low art based on mere practice whereas they viewed rhetoric as an intellectual endeavor, which is part of the liberal arts (Masterson 2004). Even though *fabrica* and *ratiocinatio* are related to these classical Greek concepts, none of them, in fact, corresponds precisely to Vitruvian definitions for he redefines them within his architectural theory.

Building upon the existing literature, this study reconsiders the prevalent duality between *fabrica* and *ratiocinatio*. It seeks interactions between *fabrica* and *ratiocinatio* in Vitruvian theory to weave their threads into each other. While it seems as though, at first, this inquiry uses weaving as a metaphor to illustrate the relationship between *fabrica* and *ratiocinatio*, the act of weaving, in fact, goes beyond a metaphor.⁷ This inquiry initiates a discussion of creating a network among the pairs of fabric/loom, matter/design, and *fabrica/ratiocinatio*. The first part will analyze the earlier uses of *fabrica* and *ratiocinatio* in ancient Greek and early Roman literature to show the similarities

and differences between the terms' origins and their definitions by Vitruvius. Then, through a close reading of Vitruvian text, it will analyze Vitruvius's redefinition of these terms based on his agenda of writing an architectural treatise, i.e., elevating architecture to the status of a liberal art. These analyses show that *fabrica* and *ratiocinatio* are not symmetrically different. This study claims that Vitruvius's contribution to these concepts put *fabrica* and *ratiocinatio* in interaction with each other. As an alternative to the doctrine of duality between the Vitruvian pair, this inquiry considers *fabrica* and *ratiocinatio* in an interwoven relationship. It argues that *fabrica* involves intellectual activity as much as *ratiocinatio* involves manual activity. While *fabrica* works in the matter, it reckons the form, and, simultaneously, while *ratiocinatio* calculates, it reckons the matter. To illustrate how they perform in matter, this study will analyze drawing in Vitruvian theory as both a product and an activity of architects.

1. VITRUVIUS'S REDEFINITION OF *FABRICA* AND *RATIOCINATIO*

Vitruvius himself is concerned with the arcane nature of architectural terms, which are neither intelligible by themselves nor in common use in his time. He sets out to provide short explanations of these terms in order to make them more intelligible to his readers (5.Pref.2). Thus, at the beginning of his first book, Vitruvius explains "*fabrica est continuata ac trita usus meditatio, qua manibus perficitur e materia cuiuscumque generis opus est ad propositum deformationis. Ratiocinatio autem est quae res fabricatas sollertia, ratione proportionis demonstrare atque explicare potest.*" (1.1.1) Morgan translates this passage as "practice is the continuous and regular exercise of employment, where manual work is done with any necessary material according to the design of a drawing. Theory, on the other hand, is the ability to demonstrate and explain the production of dexterity on the principles of proportion" (1.1.1).⁸ Based on Vitruvius's definitions, *fabrica* and *ratiocinatio* are usually translated as 'practice and theory'⁹, or 'craft and reasoning',¹⁰ focusing on the distinction between practical and intellectual sources of the architect's knowledge. Exceptionally, Granger (1931) translates them as 'craftsmanship and technology' focusing on *fabrica* and *ratiocinatio* as the sources of architect's service rather than architect's knowledge.¹¹ Whether they are the sources of the architect's knowledge or their service, the translators' word choices illustrate the doctrine of duality between the Vitruvian pair. However, the confusion around some of the Latin terms, including *meditatio*, *propositum deformationis*, *fabricates sollertia*, and *ratione proportionis*, begs for reconsideration of this doctrine. What is the role of

meditatio in manual work? What defines *propositum deformationis* for *fabrica*? How does *ratiocinatio* take into account skill (*sollertia*) and calculation (*ratione proportionis*)? Answering these questions requires a close reading of Vitruvius's definition of these terms. However, before doing so, it is crucial to study the etymology of *fabrica* and *ratiocinatio* to understand the way Vitruvius modified these terms and extended their use into architecture. The next two parts will offer a comparative study of the origins of *fabrica* and *ratiocinatio* and their definitions by Vitruvius.

1.1. *FABRICA* AS AN EXTENSION OF *TECHNĒ*

In modern English, we do not have a word that corresponds to Vitruvius's concept of *fabrica*. We have the word fabrication, whose etymology can be traced back to *fabrica*, implying the process of execution with an industrial connotation. It is more of a mechanical process. On the other hand, the Latin term *fabrica* is originated within a community of craftsmen and artisans. As a noun, *fabrica* derives from the word *faber*, which means a craftsman or an artisan who works in hard materials (Vaan 2008, 197). *Fabricāre/i*, as a verb, conveys the activity that is done by these craftsmen and artisans, i.e., "to fashion, to build, or to devise" (Vaan 2008, 197). It also implicitly conveys performing these activities skillfully because the adverb *fabre*, a derivative of *faber*, means "skillfully" (Vaan 2008, 197). Therefore, *fabrica* as a noun form of the verb '*fabricāre*' conveys the action or the process of making, building, or constructing skillfully. Furthermore, *fabrica* is semantically related to *technē* in Greek. *Technē* (skill) is etymologically linked to Proto-Indo-European root *tek-s-*, from which the Latin verb *texere* (to weave, to construct)



Figure 2: Image of a Greek *tektōn* (builder) carving the flutes of a column depicted on a bowl. (Boston Museum of Fine Arts)

is derived (Vaan 2008, 619). The English word textile, which is a synonym of fabric, derives from *texere*. Other Latin words related to textile, including *textilis* (woven, plaited), *textor* (weaver), *textūra* (weaving, structure) and *tēla* (cloth on a loom, spider's web), also derives from verb *texere* (Vaan 2008, 619). Understanding the relationship between *fabrica* and *technē* is important because it etymologically and semantically links the Vitruvian concept back to the architect. *Technē* is the root of the Greek word *tektōn*, which means artisan, craftsman, or builder, who works in hard materials. Thus, *fabrica* defines the activity of a *tektōn*.

In Greek, the word *architekton* is the combined form of *tektōn* and *archi-*, which means chief or head. Hence architect literally means chief or head builder (Barbaro 1567, 6; Parcell 2012, 25). The etymology of *architekton* suggests a shift in the architect's status from a builder who exercises manual work to a chief builder who manages not only the project but also builders.¹² Plato illustrates this status shift of the architect in his classification of knowledge. He uses kings and architects to exemplify *epitaktikē*, which is commanding knowledge classified under *gnostikē* (theoretical knowledge) rather than *praktikē* (practical knowledge) that would belong to builders (Pont, 2005). Plato sees the master-builder above the other builders. Stephen Parcell cites from Plato's conversation in the *Statesman*:

Now consider a master builder. No master builder is a manual worker – he directs the work of others... He provides the knowledge but not the manual labor ... so he might fairly be said to possess one of the theoretical forms of science ... The master builder must give the appropriate directions to each of the workmen and see that they complete the work assigned. (Parcell 2012, 31)

This status change from *tektōn*, who exercises only the craft of building, to *architekton*, who exercises the thought and commands the builders, also appears in Vitruvius's *De Architectura*. Rowland argues that Vitruvius's agenda with writing a body of architecture dedicated to Emperor Augustus is "a bold attempt to transform architecture from a manual craft into one of the liberal arts" (2014, 288). For Greeks, *technē* consists of knowledge and procedure of making. Pollitt highlights that "the Greeks felt that art at all times involved *technē*, a combination of knowledge and orderly procedure organized for the purpose of producing a specific result." (1974, 22). For Vitruvius, architecture is a combination of both *technē* and the science of multiple disciplines. He sees architecture as a systematic art governed by science and principles. He concludes the introduction of his first book by promising that "in the following books I have disclosed all the principles of the art (*omnes disciplinae rationes*)" (1.Pref.3). To perform these

principles of architecture, according to Vitruvius, the architect should have the knowledge of other disciplines, including writing, drawing, geometry, history, philosophy, music, medicine, law, and astronomy (1.1.3). On the other hand, a craftsman acquires local knowledge of a craft through his training as an apprentice in his family. An architect differs from a craftsman because he receives universal knowledge of these disciplines in addition to the knowledge of building (1.1.15).

Based on his aim of marrying architecture with the liberal arts, we can assume that Vitruvius does not offer *fabrica* as simply practice or manual activity but as practice supported by intellectual activity. For him, what differentiates the architect is his intellectual activity. Vitruvius writes:

In fact, all kinds of men, and not merely architects, can recognize a good piece of work, but between layman and the latter there is this difference, that the layman cannot tell what it is to be like without seeing it finished, whereas the architect, as soon as he has formed conception, and before he begins the work, has a definite idea of beauty (*venustate*), the convenience (*usu*) and the propriety (*decore*) that will distinguish it. (6.8.10)

Considering Vitruvius's emphasis on the intellect, his use of *meditatio* in the definition of *fabrica* becomes a crucial question. In his definition of *fabrica*, he uses *meditatio*, which is a key term to understand mental activity woven into practice. However, some scholars either overlook *meditatio* or manipulate Vitruvius's words to enhance the duality between *fabrica* and *ratiocinatio*. Watzinger argues that *meditatio* "just like Greek μελέτη (*melētē*) designates the purely practical exercise and experience" (Watzinger 1909, 203). This position puts *fabrica* in opposition to *ratiocinatio*, which is purely theoretical. However, *meditatio* is derived from *meditos*, which belongs to *medeor*, meaning "to be a judge, to give a judgement." Hence, Vaan argues, *meditate/o* means "to judge constantly, contemplate" (2008, 365). In contrast to Watzinger, who refuses the intellectual capacity of *meditatio*, Perrault accepts *meditatio* as contemplation and, in fact, uses *meditatio* to describe how the theoretical knowledge is gained, rather than practical knowledge as Vitruvius originally wrote (Perrault 1692, 24).

Vitruvius's use of *meditatio* to describe *fabrica* is not random nor unintentional. *Meditatio* means contemplation (of an action) or the action of devising, planning, thinking out. In Barbaro's interpretation of *fabrica*, the word *meditatio* plays a key role. According to Barbaro, *meditatio* brings *fabrica* closer to *ratiocinatio*. He translates *fabrica* as "continuous and exercised thought (*meditatio*) about the use, ..." ¹³ (Barbaro 1567, 8). Gwilt emphasizes the intellectual role of *meditatio* in his translation. He translates, "[p]ractice is the frequent

and continued contemplation of the mode of executing any given work, or of the mere operation of the hands, for the conversion of the material in the best and readiest way" (Gwilt 1826, 3). Unlike the common interpretations of the relationship between *fabrica* and *ratiocinatio*, Vitruvius does not prioritize thought over manual work. *Meditatio* in *fabrica* implies that thought as reckoning and computing was employed before and during the work in addition to thought as reflection carried out over the completed work. He defines *fabrica* and *ratiocinatio* as interdependent through the work of the architect.

1.2. RATIOCINATIO AS THE EXTENSION OF RHETORIC

Similar to *fabrica*, *ratiocinatio* is a term originated outside of architecture. Vitruvius borrows it from rhetoric and redefines it within the framework of his architectural theory. Rhetoric, in fact, had a significant influence on Vitruvian theory. In his analysis of *De Architectura*, Callebat asserts that the role of rhetoric in Vitruvius's treatise is more than a literary system of writing. "It is also, and more deeply—in a close encounter with architecture—that of an agent of conceptualization and theorization"¹⁴ (1994, 34). Scholars have pointed out the similarities between Vitruvius's description of an architect's education and Cicero's definition of an orator's education (Romana 1987; Masterson 2004; McCoy 2017).¹⁵ Moreover, besides *ratiocinatio*, Vitruvius borrows several other rhetoric concepts, including *ordinatio*, *distributio*, and *decor*. However, Vitruvius does not directly use them but adapts them into architecture so that he intersects craft and liberal arts. Similar to his redefinition of *fabrica* as the combination of manual and intellectual work as an extension of *technē*, he applies the same strategy to *ratiocinatio* to extend its use into architecture. Perrault's translation of *ratiocinatio* as *la theorie* in 1673 becomes the prevalent translation among Vitruvian scholars. However, as McEwen points out, Perrault's word choice is misleading because the Latin term *ratiocinatio* does not have a Greek equivalent, and the Greek *theoria* has much to do with observation and seeing (McEwen 2004, 6-7). *Ratiocinatio* derives from the Latin root *ratio* meaning 'calculation, account, reason' (McEwen 2004, 7). In Greek, *ratio* corresponds to *logos* meaning 'calculation, reason' and 'speech, word.' It comes from PIE root *leg-* meaning to collect, or to gather. Derivatives of *leg-* also mean to speak and to gather words in a speech (McEwen 2003, 60). The etymology of *logos* in Greek shows the rhetorical roots of *ratiocinatio*.

Scholars emphasize the rhetorical role of *ratiocinatio* as argumentation. Watzinger draws attention to Cicero's view on the eloquence of an architect. When Cicero writes about the famous

Greek architect, Philo, who built an arsenal in Athens, he compares the architect to an orator. He claims the architect's eloquence does not come from the art of the architect, but from that of the orator. Thus, Watzinger argues that the ability to talk about the principles that governed his work was particularly significant for the ancient architects (Watzinger 1909). Moreover, Barbaro (1567) and Frezouls (1985) see the architect's prominent characteristic as being able to reflect on works. For Barbaro, the ability to judge other works is the differentiation quality (*differentia specifica*) of an architect. *Ratiocinatio* as *discurso* (discourse¹⁶) enhances the ability of judgment (Barbaro 1567). Under the influence of *ratiocinatio*'s rhetorical role, these scholars argue that *fabrica* comes first, before *ratiocinatio*.

Focusing on its rhetorical role, it is claimed that *ratiocinatio* produces knowledge through criticizing and reflecting on work. The interpretation of *ratiocinatio* as the intellectual reflection on the fabricated work causes a gap in the theory where "there is no *ratiocinatio* without a prior *opus*, there is no pure theoretical reflection, but an analysis of the practice"¹⁷ (Frezouls 1989, 41). Frezouls argues that an architect can still build without theory, but there is no building to talk about without practice. He sees *fabrica* synonymous with *opus* (work), and *ratiocinatio* as the reflection or explanation of the work (Frezouls 1989, 41). His interpretation reduces not only *fabrica* to a work but also *ratiocinatio* to a discussion. However, according to Vitruvius, there is no gap between *fabrica* and *ratiocinatio*; on the contrary, they are inseparable (Granger 1925, 68). Both *fabrica* and *ratiocinatio* are required to acquire proper knowledge of architecture. Vitruvius wrote, "architects who aimed at acquiring manual skill without scholarship have never been able to reach a position of authority to correspond to their pains, while those who relied on only upon theories and scholarship were obviously hunting the shadow, not the substance" (1.1.2). He compares the architect who acquired the knowledge of both *fabrica* and *ratiocinatio* to a fully armed man ready to build his work speedily and defend it with authority. However, it is not Vitruvius's only focus. Vitruvius extends the use of *ratiocinatio* from rhetoric into practice. Rather than a discussion, Perrault sees *ratiocinatio* as reasoning that directs the practice (1973, 1).¹⁸ Similarly, Galliani argues *ratiocinatio* ensures the best possible layout of future work (Galliani 1758, xvi).¹⁹

In Vitruvian theory, *ratiocinatio* is active not only after the work is complete to criticize it, but also during the execution to ensure the coherency in the work. As Indra McEwen points out, for Vitruvius, *ratio*, the root of *ratiocinatio*, provides the work with coherency. Any work produced with reason or rationale would

provide authority to its architects (McEwen 2003). Thus, *ratiocinatio* is not only a rhetorical act, but it is also a design act that guarantees the success of the work. As Vitruvius explains in his fifth principle: "Propriety (*decor*) is perfection of style which comes when a work is authoritatively (*cum auctoritate*) constructed and approved principles" (1.2.5).²⁰ Vitruvius emphasizes the role of *ratiocinatio* as the source of authority. It provides authority to a work by ensuring the work is carried out through principles supported by the knowledge of other sciences (1.1.2). It also defends the authority of the work by demonstrating and explaining these principles. Vitruvius extends the use of *ratiocinatio* outside of its rhetorical notion. He defines *ratiocinatio* as an act that provides both persuasion and coherence in work. Therefore, in Vitruvian theory, *fabrica* and *ratiocinatio* perform simultaneously in architecture, not only during the design but also after the design is carried out. However, such a statement raises further questions: how do *fabrica* and *ratiocinatio* work together? How do they interact in architecture?

2. *FABRICA* AND *RATIOCINATIO* INTERWOVEN IN DRAWING

Drawing is a key concept in Vitruvian theory. In his essay "*Vitruve et le Dessin d'Architecture*," Frezouls emphasizes the significance of drawing for Vitruvius by pointing out that "... drawing is present at every level of Vitruvian theory,"²¹ (1985, 220) including *fabrica* and *ratiocinatio* as well. He asserts that drawing is the contact point between the architect's mental and manual activity, referring to *ratiocinatio* and *fabrica*, respectively (1985, 228). According to Frezouls, drawing is a mode of realization that belongs to the preparation phase. It is evoked by calculation and used as a base for execution (Frezouls, 213-214). Considering drawing as only a mode of realization supports Frezouls' argument; however, for Vitruvius, drawing is not only a tool but also a skillful and systematic activity. Based on Vitruvius's definition of drawing both as a skill and knowledge, this study claims that *fabrica* and *ratiocinatio* interact with each other on multiple levels in work. This part analyzes the role of drawing in *De Architectura* to understand how Vitruvius set *fabrica* and *ratiocinatio* in interaction. Firstly, it will study drawing as a medium that serves both *fabrica* and *ratiocinatio*, and then, analyze it as the activity the architect performs to reveal the complex relationship between the two concepts.

In the first chapter of his first book, Vitruvius defines drawing as both a skill and knowledge. Vitruvius wrote that an architect should be "skillful with pencil" (*peritus graphidos*) (1.1.3). Later in the same chapter, he added that an architect could not be a painter as skillful as Apelles; he must not be "unskillful in drawing"

(*graphidos non inherits*) (1.1.13). After emphasizing drawing as a skillful activity, Vitruvius lists drawing, in addition to other liberal arts, as a science (*graphidos scientiam*) that an architect should be educated in. He says the architect "must have the knowledge of drawing so that he can readily make sketches to show the appearance of the work which he proposes" (1.1.4). Besides being a skill carried out by hand, drawing is also a systematic knowledge supported by other sciences and theories. Kanera argues that Vitruvius's introduction of drawing along with the other sciences in his education program for the architects caused a change in Renaissance authors' view of drawing in relation to sciences. In the middle ages, science is privileged over drawings, which were seen as a simple craft. After Vitruvius's manuscripts were made available to scholars, Renaissance authors and architects accepted Vitruvius's view as an authoritative proof of the high value of drawing (Kanerva 2006, 175-76). As drawing becomes fundamental to architecture, Vitruvius's double formulation of drawing both as a skill and as knowledge also enhances his goal of elevating architecture's status to the level of a liberal art. It is no longer simply manual activity of craftsmen, but an activity of architects evoked by both *fabrica* and *ratiocinatio*. Therefore, drawing is more than a single contact point between manual and mental activity, as Frezouls argued. It must be a result of a tangled relationship between *fabrica* and *ratiocinatio*.

For Vitruvius, drawing, as a mode of realization, serves not only for *fabrica* to show the form given to the matter but also for *ratiocinatio* to demonstrate and explain the work. Even though only a few samples of architectural drawings from the ancient Greek and early Roman period survived today, it is clear that ancient architects often used drawings to convey their ideas to builders and commissioners.²² While they also used textual and verbal descriptions of their projects, they referred to drawings whenever the project got too complex to describe through words (Corso 2016; Gros 1996). For example, explaining a simple house layout through the verbal or textual medium was easy, but a complex project like a bathhouse required visual representation (Corso 2016, 24). Vitruvius writes that architects use drawing "to show the appearance of the work which he proposes" (1.1.4). Architects transfer their *idea* onto drawing to show how builders ought to construct a wall, or carve a column, or paint decorations. Besides using drawing as a preparatory medium for the execution of a work, ancient architects, including Vitruvius, also used drawings in addition to their text to illustrate their comments. In *De Architectura*, Vitruvius offers ten drawings for which he uses the words *forma*, *schema*, *diagramma*, or *exemplar*.²³ He mentions these drawings or refers back to them

LIBER

TERTIVS

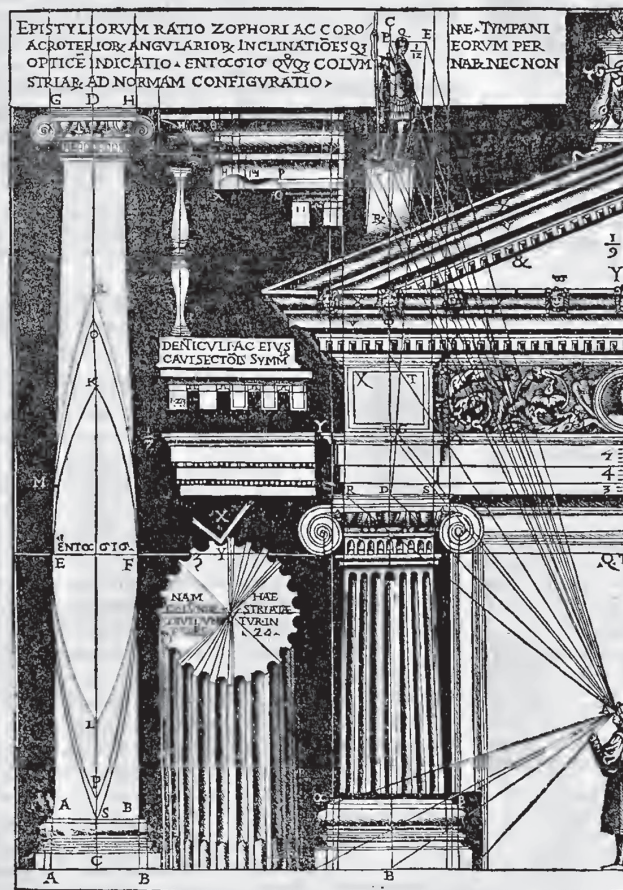
LX.

Ma le altre cō eguale modo disposite: acioche singula singulis: seu ciascuna a ciascuna a le medie tegule se rispondano: In questa parte Vitruuio non solum ostende el collocare de quistū capi leonini sotto le medie tegule per la integritate sua: ma etiam

insigna il modo de coprire queste sorte de quale generatione de tegule: aut imbrice: o di laistre al modo de le coperture de li Cōmensi & per la Germania & la Galia Transalpina si usa: aut como antiquitus: & etiam in hodiernum diem in molti loci: si in la Italia quanto etiam altroue sono usati de uaria op̄ra cothilie: uel figulina vitrata al modo de germania ut diximus & altriloci. Ma queste che saranno contra le colonne Il testo da se mi pare chiaramente si explica: & tanto piu quanto la figura te indica queste grondatione seu stylicidante collocatione o siano uerso il Tympano procurrente uel altro modo si pono collocare. E cosa scienda che queste generatione de colūne Ionice siano state

Ma le altre cō eguale modo disposite: acio che ciascuna a ciascuna medie tegule se rispondano. Ma queste che saranno cōtra le colūne siano perforate al canale: quale excipe da le tegule laqua cōeleste. Ma li capi mediani siano solidi acio che la forza del aqua: quale cade per le tegule in lo canale non se expanda difora p li intercolumniū: ne anche perfunda le persone che passano: Ma quelle che sono cōtra le colūne si uedano emittre da la bocha le uomētie de il ruoto de le aque: De le acde Ionice quanto ap̄rissimamēte ho potuto le loro dispositione in questo uolumine ho descritto: Ma de le Dorice & Corinthie: qual siano le sue proportionē in lo sequentelibro explicaro.

da li antiqui diuise in uarie symmetrie le loro striature: Alcuni hano diuiso il scapo in lo modo che hauerno de le Thufcanice columne: In lo insequente libro quarto: Alcuni perho uolendo che queste Ionice: & cōsi epse Thufcanice che sono mancho ca nate de striature de ruote altre siano perho diuise nisi per fare uigintiquattro strie: chi ha coparito li loro scapi in parte septanta due: dando due parte in lo cauo de la stria: & una a lo striglo exteriore: Alcuni altri hano distincti li p̄dicti scapi: In parte nona ginta sex faciendo etiam il dicto striglo sia nisi una parte: & tre siano tribuite a li caui di epse sine.



H iiii

Figure 3: Entasis diagrams from Cesarino's Italian Translation in 1521. (Cesarino 1521, LX)

multiple times throughout the ten books. Gros argues that despite Vitruvius's goal of producing a textual body of architectural theory, "the figure takes over from the text only in cases very punctual when Vitruvius is aware of having reached the limits of his formulation and/or conceptualization"²⁴ (Gros 2006 [1996], 328).

In addition to viewing drawing as a visual representation, Vitruvius also conceptualizes it as a procedural action performed by architects' hands and minds. One of the ten drawings promised by Vitruvius, a diagram of winds can be reconstructed by following Vitruvius's description of the drawing. Vitruvius provides a procedural description of how to construct the diagram. He writes:

Let A be the center of a plane surface, and B the point to which the shadow of the gnomon reaches in the morning. Taking A as the center, open the compass to the point B, which marks the shadow, and describes a circle. Put the gnomon back where it was before and wait for shadow to lessen and grow again until in the afternoon it is equal to its length in the morning, touching the circumference at the point C. Then from point B and C describe with the compasses two arcs intersecting at D. Next draw a line from point of intersection D through the center of circle to circumference and call it E F. This line will show where the south and north lie. (1.6.12)

Although this is the only diagram in his treatise that can be completely reconstructed by following his procedural descriptions, it clearly shows that Vitruvius considers drawing as an activity that the mind and hands perform together. The mind follows the systematic information and the hands trace lines on a surface. He continues by saying, "then find with the compasses a sixteenth part of the entire circumference; then center the compasses on the point E where the line to the south touches the circumference and set off the points G and H to the right and left of E" (1.6.13). He describes drawing as an activity that produces a geometric pattern and as a method to calculate and measure the geometry. Mind calculates through making and drawing. The motion between mind and hands becomes cyclic.

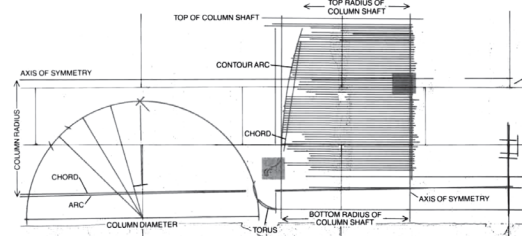


Figure 4: Three overlapping drawings showing the shape of a column and two vertical cross-sections of a column are traced over a photograph from Temple of Apollo by Haselberger. The vertical cross-section shows the *entasis* of the column. (Haselberger 1985, 130)

Vitruvius himself also explains that when his ideas or the geometry gets too complex that he cannot afford to describe them through texts, and he resorts to drawing. According to him, knowledge of geometry helps architects draw these complex projects by teaching them how to use the rule and compass. He writes, "[g]eometry, also, is of much assistance in architecture, and in particular it teaches us the use of the rule and compass by which especially we acquire readiness in making plans for buildings in their grounds, and rightly apply the square, the level, and the plummet" (1.1.4). He added that the geometrical theories and methods assist architects to resolve the difficult question involving symmetry (*difficilesque symmetriarum quaestiones*), which is one of his six principles. By geometry, Vitruvius does not mean a visual depiction of a building, but a system of proportion or a formulation of relations between its elements. Vitruvian man, Vitruvius's textual formulation of the ideal body (3.1.2), exemplifies his understanding of geometry. As McEwen points out Vitruvian man is neither a depiction nor a product of geometry, rather, it is the source of geometry (2003, 157). Considering Vitruvius's statement about geometry's role, it is not surprising that he used three out of ten drawings in his third book in which he describes the symmetry of temples. One of these drawings presents *entasis*, a slight enlargement made in the middle of a column to fix the optic deformation on straight shafts searching for beauty. Vitruvius promises a figure and calculations of *entasis* at the end of the third book (3.3.13); however, they are not found in any of the manuscripts. Early editors and translators of *De Architectura* offered a figure of entasis based on archeological findings and measurements (figure 3a-b). In 1989, archeologist Haselberger found incised drawings, one of which shows the calculation of a column's entasis on the walls of the Hellenistic Temple of Apollo in Didyma (figure 4) (Haselberger 1985). Even though it is not sure whether this drawing and calculation correspond to what Vitruvius provided in his manuscript, this discovery proves that specific calculations described in drawings are used by Hellenistic architects during the construction phase.

While the two entasis drawings, one is described in *De Architectura* and the other one is drawn in the Temple of Apollo, show the link between theory and practice, another tracing depicting the temple's layout reveals more important information on the use of drawing as a design medium among ancient architects. This tracing of the layout found on the base of the Temple of Apollo shows alterations in the geometry and proportions of the layout in time. Therefore, this drawing is both a construction-drawing and a design-drawing that is open for changes even

during the construction phase (Jones 2003). Design usually precedes construction, yet in this particular example, design continues during the construction. The altered traces on the stone surface imply that drawing becomes a medium upon which the changes in design are reflected. Changes also impact the construction in terms of the form, dimensions, and position of elements. Vitruvius's theory also highlights the significant role of drawing in design. Vitruvius mentions that plan drawing (*ichnographia*), elevation drawing (*orthographia*), and perspective (*scaenographia*) as the expressions (*ideai* in Greek) of his second principle of architecture, *dispositio*, which "includes the putting of things in their proper places and the elegance of effect which is due to adjustments appropriate to the character of the work" (1.2.2). It is not unusual that Vitruvius defines these three forms of drawing as an activity. He writes:

A ground plan is made by the successive use of compasses and rule, through which we get outlines for plane surfaces of buildings. An elevation is a picture of the front of a building, set upright and properly drawn in the proportions of the contemplated work. Perspective is the method of sketching a front with the sides withdrawing into the background, the lines all meeting in the center of a circle. (1.2.2)

Vitruvius adds that these drawings come from reflection (*cogitatione*) and invention (*inventione*).

Reflection is careful and laborious thought, and watchful attention directed to the agreeable effect of one's plan. Invention, on the other hand, is the solving of intricate problems and the discovery of new principles by means of brilliancy and versatility. (1.2.2)

Vitruvius defines reflection and invention as intellectual activities solving the problems of architecture. Furthermore, these intellectual activities are carried out through practice. In his third book, Vitruvius praises Hermogenes for developing a new principle of the pseudo-dipteral octastyle temple. Hermogenes's invention saves expense and labor and provides a much wider space for walking around the cella and sheltering during the rain. He achieves these by "dispensing with the inner rows of thirty-eight columns which belonged to the symmetry of the dipteral temple" (3.3.8). He changed the layout by removing some columns and rearranging the proportion that would "preserve the dignity of the whole work" (3.3.8). While developing this new layout, according to Vitruvius, Hermogenes takes into account not only quantitative calculations like geometry for the proportion, arithmetic for calculating the expenses but also qualitative reckoning like the use of space, dignity, and beauty of the whole work. While solving such complex issues, Hermogenes relies on both *ratiocinatio* and *fabrica* to produce a coherent work

through calculation and execution. Hermogenes's novel work shows that reflection and invention are not only about the intellectual activity but also about making, visualizing and crafting. There is no gap between *fabrica* and *ratiocinatio*. For example, drawing is both a manual and mental exercise, where the architect learns and advances their thought by practicing, and vice versa.

CONCLUSION

The confusion around the relationship between *fabrica* and *ratiocinatio* in Vitruvian theory echoes in whether *De Architectura* is a practical manual on know-how of architectural profession or a theoretical text on knowledge of architectural discipline (Frezouls 1989, Jones 2000, Fitzpatrick 2017). Is *De Architectura* a product of practice or of theory? Considering the historical influence of Vitruvian thoughts in both architectural practice and architectural theory, it is clear that no such distinction can be made for *De Architectura*. As Frezouls claims, Vitruvius had the goal of producing a complete body of work dedicated to a collection of directions for building and also principles for the art of building. He writes:

The double formulation according to which the work is presented both as a collection of *praescriptiones terminatae* and as a logical statement of architecture—*omnes disciplinae rationes*—suggests well for the treaty two distinct perspectives: a practical guide, allowing to construct all kinds of buildings but also that of a work giving access—overview—to the logical sequences which make architecture not only know-how but knowledge.²⁵ (Frezouls 1989, 40)

Considering the double purpose of *De Architectura*, this essay examined the false duality between the two significant components of architect's knowledge, *fabrica* and *ratiocinatio* in Vitruvian theory. Rather than focusing on the prevailing opposition between the Vitruvian pair, this inquiry sought to reveal the interactions between *fabrica* and *ratiocinatio*.

The etymology and early use of both *fabrica* and *ratiocinatio* confirms an opposition between these two terms. *Fabrica* as a craft term implies the work of a craftsman, an artisan or a builder. It is concerned simply with the practice or/and knowledge of that practice. On the other hand, *ratiocinatio* is a rhetorical term concerning with argumentation, reasoning and structuring of a speech or thought. In Vitruvian theory, we see that the use of both concepts is extended into architecture. Vitruvius sees architecture as an art combining both manual and intellectual production. For example, drawing is not simply a representation produced by physically drawing with a pen on paper. As much as it is a physical activity, it is also an intellectual activity (*meditatio*)—an exercise of thought through motion. Vitruvius shifts the

meaning of *fabrica* from mere craft to both manual and intellectual act by emphasizing *meditatio* in its definition. Likewise, thought is not merely a mental activity, but a contemplation on/through practice taking into account both skill and calculation (*sollertia et ratione proportionis*). Drawing clearly illustrates the interaction between *fabrica* and *ratiocinatio*. Drawing is produced and used by both *fabrica* and *ratiocinatio*. They use drawing to demonstrate and explain the work whether it is in-situ showing the details of construction, or in text illustrating the argument. As Vitruvius implies, drawing is a thought exercise carried out through manual activity of hands. There is no gap between thought and activity, i.e., both *fabrica* and *ratiocinatio* make use of drawing and operates through mind and hands simultaneously.

This inquiry sees Vitruvian theory as a fabric of relations in which both *fabrica* and *ratiocinatio* are in an interwoven relationship. While the metaphor of weaving illustrates the relationship between *fabrica* and *ratiocinatio*, this inquiry aims at extending weaving beyond a metaphor to create a material link between fabric and *fabrica*, and loom and *ratiocinatio*. The act of weaving suggests a direct relationship between matter and thought, making and thinking. This study lays the groundwork for future research on the relationship between Vitruvius's theoretical frameworks. Within this fabric of Vitruvian theory, a significant question remains to be answered. How do *fabrica* and *ratiocinatio* interact with Vitruvius's other two theoretical frameworks: the principles of design and the triadic structure of architecture?

ENDNOTES

- 1 There are several English translations of Vitruvius's *De Architectura* including Gwilt (1826), Morgan (1914), Granger (1931), Rowland and Howe (1999), Smith (2003) and Schofield (2009). In this essay, I use Morgan's 1960 edition of his 1914 translation.
- 2 Berardo Galiani (1758, xv).
- 3 As Branko Mitrović (2019, xi-xxxviii) cites from Barbaro's commentary on Aristotle's *Rhetoric* (1542a).
- 4 F. I. G. Rawlins (1950).
- 5 Frezouls warn us against the assimilation of Vitruvian couple to *technē* and *epistēmē*, however, he fails to avoid from comparing them to Aristotelian *ergon* and *logos*. Frezouls (1989, 41) writes "*Sans reprendre une discussion engagée ici-même, observons la prudence qu'elle nous conseillait: il vaut mieux éviter d'assimiler ce couple à l'opposition grecque classique entre technē et epistēmē. Toutefois on ne peut manquer de rapprocher le binôme de celui, encore plus banal, que forment ergon et logos, avec l'avantage de trouver ici pour logos un glissement sémantique-homologue de celui qu'on observe pour ratiocinatio--du sens de parole au sens plus dense de "discours, raisonnement, raison".*"
- 6 Graham Pont (2005) links Vitruvius' division of architectural knowledge into practice and theory to Plato's distinction between the science of knowledge (*praktikē*) and the science of mere knowing (*gnostikē*).
- 7 Weaving played a central role in Greek *oikos* (household). Looms were the central artifact of ancient Greek houses. Thanks to its material presence in Greeks' daily lives, fabric and weaving emerged as a rich metaphor in their culture, especially in their art. For more on the metaphor of fabric and weaving in Greek and Roman myth and society, see *The Craft of Zeus* by John Scheid and Jesper Svenbro (1996).
- 8 Translation by Morris Hicky Morgan (1960). The Latin text is added in parenthesis by the author.
- 9 Claude Perrault (1673) uses '*la pratique et la théorie*' for the first time in his French translation. Berardo Galiani (1758) translated them as '*la pratica e la theorica*' in Italian. 'Practice and theory' become the common word choice among English translators: Joseph Gwilt (1826), Morris Hickey Morgan (1914), Ingrid Rowland and Thomas Howe (1999), Richard Schofield (2009).
- 10 Thomas Gordon Smith (2003).
- 11 Frank Granger suggests that *fabrica* and *ratiocinatio* are the source of architect's service rather than their common interpretation as the source of architect's knowledge. Granger grounds his interpretation on the mispunctuation in the first two sentences of the first book. He claims that the first sentence ends with *perficiuntur* and the second sentence starts with *opera* and reads as "*Opera ea nascitur et fabrica and ratiocinatione.*" Hence *opera* defines 'personal service' of an architect and it "consists in craftsmanship and technology." (Granger 1931, 6-7).
- 12 J.J. Coulton (1977) gives a detailed analysis of the relationship between architect, patron and project in the first chapter of his book *Ancient Greek Architects at Work*. Moreover, in his article "The Fall of the Tektōn and The Rise of the Architect", Jonas Holst gives a thorough analysis of changing values of *tektōn* as a craftsman throughout the antiquity.
- 13 Translated by the author. Barbaro (1567, 8) wrote, "*Fabrica è continuo, & essercitato pensiero dell'uso, che di qualunque materia, che per dar forma all'opera proposta si richiede, con le mani si compie.*"
- 14 Translated by the author from French. Callabat (1994, 34) wrote, "*La fonction de la rhétorique, dans le De architectura, n'est pas cependant celle seulement d'un système littéraire de l'écrit, d'un moyen efficace de communication ou d'une valorisation culturelle. Elle est aussi, et plus profondément--dans une rencontre étroite avec l'architecture--celle d'un agent de conceptualisation et de théorisation.*"
- 15 Elisa Romana (1987), Masterson (2004, 393), Harris-McCoy (2017, 111).
- 16 Translated by Kim Williams (2019).
- 17 Translated by the author. Frezouls (1989, 41) wrote: "... il n'y pas de ratiocinatio sans opus préalable, il n'y pas de réflexion théorique pure, mais une analyse de la pratique."

- 18 In his translation Perrault (1673, 2) notes that he doesn't prefer to translate *ratiocinatio* as *raisonnement* (reasoning) because it is too general, and *fabrica* as *fabrique* (fabricated) because it is not French.
- 19 Translated by the author. Galiani (1758, xvi) wrote, "*La Teorica consiste nel sapere concepire la miglior distribuzione di una dato spazio, per formarvi co'dati materiali tutti i maggiori comodi, che si possono secondo la mente del padrone, e secondo la somma, ch'egli vi vuole impiagare.*"
- 20 The original Latin term '*decor*' as used by Vitruvius is given in the parenthesis by the author.
- 21 Translated by the author. Frezouls (1985, 220) writes, "*Quoi qu'il en soit de ce point particulier, on doit convenir que le dessin est présent à tous les niveaux de la réflexion générale de Vitruve, et donc, certainement, pour une large part, de ses sources.*"
- 22 Corso (2016) gives a thorough study of drawing in ancient Greece and Roman Empire. He studies drawing in Greek and Roman architecture through archeological and textual sources. More can be found in Antonio Corso, 2016. *Drawings in Greek and Roman Architecture*. Oxford: Archaeopress Publishing.
- 23 In the first book, Vitruvius mentions two drawings: one showing the directions of winds and the other one showing the networks of the roads of a city. In the third book, he mentions a drawing concerning *entasis* and a drawing and a formulation of an ionic column's volutes. In addition to them, he offers a drawing of altars in book four, a diagram explaining *echeia* in book five, a drawing of chorbates in book eight, a schema of duplication of the squares, and a drawing showing the position of ladders with indications of the levels of steps in the book nine and finally a drawing of Archimedes's screw in the book ten.
- 24 Translated by the author. Gross (2006, 14) writes, "*Il apparaît ainsi que la figure ne prend le relais du texte que dans les cas très ponctuels où Vitruve a conscience d'avoir atteint les limites de sa formulation et/ou de sa conceptualization.*"
- 25 Translated by the author. Frezouls (1989, 40) writes, "*La double formulation selon laquelle l'ouvrage est présenté à la fois comme un recueil de praescriptiones terminatae et comme un exposé logique de l'architecture--omnes disciplinae rationes--suggère bien pour le traité deux perspectives distinctes: celle d'un guide pratique, permettant de construire toute espèce de bâtiments mais aussi celle d'un ouvrage donnant accès--aperçu--aux enchaînements logiques qui font de l'architecture non pas seulement un savoir-faire mais un savoir.*"

REFERENCES

- Barbaro, Daniel. 1567. *I Dieci Libri dell'Architettura di M. Vitruvio, Tradotti & Commentati*. Venetia: appresso Francesco de'Franceschi Senese and Giovanni Chrieger Alemanno.
- Callebat, Louis. 1994. "Rhétorique et architecture dans le «De Architectura» de Vitruve," in *Le projet de Vitruve. Objet, Destinataires et Réception du De architectura Actes du Colloque International de Rome*. Rome: École Française de Rome.
- Callebat, Louis. 2001. "Fabrica et Ratiocinatio dans le De Architectura". *Imaginaire et Modes de Construction du Savoir Antique dans les Textes Scientifiques et Techniques*. Perpignan: Presses Universitaires de Perpignan.
- Cesarino, Cesare, Mauro Bene and Benedetto Giovio. 1521. *Di Lucio Vitruvio Pollione De Architectura Libri Dece Traducti de Latino in Vulgare Affigurati: Comentati: Et con Mirando Ordine Insigniti: Per il Quale Facilmente Portrai Trovare la Moltitudine de li Abstrus et Reconditi Vocabulia li Soi Loci et in Epsa Tabula con Summo Studio Expositi et Enucleati ad Immensa Utilitate de Ciascuno Studioso et Benivolo de Epsa Opera*. Milan: Gotardo da Ponte.
- Corso, Antonio. 2016. *Drawings in Greek and Roman Architecture*. Oxford: Archaeopress Publishing.
- Coulton, J. J. 1977. *Ancient Greek Architects at Work: Problems of Structure and Design*. Ithaca: Cornell University Press.
- Fitzpatrick, Nichols Marden. 2017. *Author and Audience in Vitruvius's De Architectura*. Cambridge: Cambridge University Press.
- Frezouls, Edmond. "Fondements Scientifiques, Armature Conceptuelle et Praxis Dans le De Architectura" in *Munus Non Ingratum: Proceeding of the International Symposium on Vitruvius's De Architectura and the Hellenistic and Republican Architecture*. Leiden: Stichting Bulletin Antieke Beschaving: 39-48.
- Frezouls, Edmond. 1985. "Vitruve et le Dessin d'Architecture," in *Le Dessin d'Architecture dans les Sociétés Antiques, Actes du Colloque de Strasbourg*. Strasbourg: Brill Archive
- Galiani, Berardo. 1758. *L'architettura di M. Vitruvio Pollione: Colla Traduzione Italiana e Comento*. Napoli: Nella Stamperia Simoniana.
- Gargano, Maurizio. 2006. *Forma e Materia: Ratiocinatio e Fabrica nell'Architettura dell'Età Moderna*. Rome: Officina.
- Giacando, Fra Giovanni. 1511. *M. Vitruvius per locundum Solito Castigator Factus, Cum Figuris et Tabula, ut iam Legi et Intellegi Possit*. Venice: Giovanni de Tradino alias Tacuino.
- Granger, Frank. 1925. "Vitruvius's Definition of Architecture." *The Classical Review* Vol. 39, 3/4: 67-69.
- Granger, F. and Vitruvius. 1983. *Vitruvius on Architecture*. Cambridge, Mass: Harvard University Press. (original publication in 1931).
- Gros, Pierre. 2006. "Les Illustrations du De Architectura de Vitruve: Histoire d'un Malentendu," in *Vitruve et la Tradition des Traités d'Architecture: Fabrica et Ratiocinatio*. Rome: l'École Française de Rome: 325-339.
- Gwilt, J. and Vitruvius. 1826. *The Architecture of Marcus Vitruvius Pollio in Ten Books*. London: Priestley and Weale.
- Halsenberger, Lothar. 1985. "The Construction Plans for the Temple of Apollo at Didyma." *Scientific American* Vol. 253, 6: 126-133.

- Harris-McCoy, Daniel. 2017. "Making and Defending Claims to Authority in Vitruvius's *De Architectura*." In *Authority and Expertise in Ancient Scientific Culture*. Cambridge: Cambridge University Press. 107-128.
- Holst, Jonas. 2017. "The Fall of the *Tektōn* and The Rise of the Architect: On the Greek Origins of Architectural Craftsmanship." *Architectural Histories*, 5 (1): 1–12.
- Jolles, J. A. 1905. *Vitruvs Aesthetik*. Freiburg: Universitäts-Buchdruckerei.
- Jones, Mark Wilson. 2009. *Principles of Roman Architecture*. New Haven and London: Yale University Press.
- Kanerva, Liisa. 2006. *Between Science and Drawings: Renaissance Architects on Vitruvius's Educational Ideas*. Vaajakoski: Finnish Academy of Science and Letters.
- McEwen, Indra Kagis. 2003. *Vitruvius: Writing the Body of Architecture*. Cambridge: MIT Press.
- McEwen, Indra Kagis. 2004. "Vitruvius, or the Hidden Menace of Theory." *Auf Der Suche Nach Einer Theorie der Architektur* Band 12.
- Mitrović, Branko. 2019. "Daniele Barbaro's Architectural Theory" in *Daniele Barbaro's Vitruvius of 1567*, ed. Kim Williams. Birkhäuser: xi-xxxviii.
- Morgan, M. H. and Vitruvius. 1960. *Vitruvius: The Ten Books on Architecture*. New York: Dover Publications.
- Parcell, Stephen. 2012. *Four Historical Definitions of Architecture*. Montreal: McGill-Queen's University Press.
- Perrault, Claude. 1673. *Les Dix Livres d'Architecture de Vitruve, Corrigez et Traduits Nouvellement en François, avec des Notes & des Figures*. Paris: Chez Jean Baptiste Coignard.
- Perrault, Claude. 1674. *Abregé des Dix Livres d'Architecture de Vitruve*. Paris: Chez Jean Baptiste Coignard.
- Perrault, Claude. 1692. *An Abridgment of the Architecture of Vitruvius*. London: Abel Swall and Timothy Child.
- Pollitt, J. J. 1974. *The Ancient View of Greek Art: Criticism, History, and Terminology*. New Haven and London: Yale University Press.
- Pont, Graham. 2005. "The Education of Classical Architect from Plato to Vitruvius." *Nexus Network Journal* Vol. 7-1: 76-85.
- Rawlins, F. I. G. 1950. "Episteme and Techne." *Philosophy and Phenomenology Research* Vol. 10, 3: 389-397.
- Romano, E. 1987. *La capanna e il tempio: Vitruvio o dell'architettura*. Palermo: Palumbo.
- Romano, Elisa. 2017. "Si qui voluerit Vitruvius on Architecture as 'the Art of the Possible'." *Knowledge, text and Practice in Ancient Technical Writing*. Cambridge: Cambridge University Press. 53-67.
- Rowland, Ingrid D. 2005. "From Vitruvian Scholarship to Vitruvian Practice." *Memoirs of the Academy in Rome*. Rome: The American Academy in Rome. 14-40.
- Rowland, I. D., Thomas N. Howe and Vitruvius. 1999. *Vitruvius Ten Books on Architecture*. Cambridge: Cambridge University Press.
- Scheid, John and Jesper Svenbro. 1996. *The Craft of Zeus: Myths of Weaving and Fabric*. Trans. By Carol Volk. Cambridge, Mass. And London: Harvard University Press.
- Schofield, R. and Vitruvius. 2009. *Vitruvius on Architecture*. Penguin Classics.
- Smith, T. G. and Vitruvius. 2003. *Vitruvius on Architecture*. The Monacelli Press. Vaan, Michiel de. 2008. *Etymological Dictionary of Latin and the other Italic Languages*. Leiden, Boston: Brill.
- Watzinger, Carl. 1909. "Vitruvstudien." *Rheinisches Museum für Philologie* Vol. 64: 202-223.
- Williams, Kim. 2019. *Daniele Barbaro's Vitruvius of 1567*. Birkhäuser.

OUTSIDE KNOWING: Accessing Alterity in the Nocturnal Urban Landscape

Clair Downey
University of Limerick

Abstract: Michel Foucault qualified the writing of Maurice Blanchot as ‘thought from the outside’. The reference is to absence or, the ability of what we cannot know to shed light on what we seek. In the context of the present-day, European city, connections to existing cultural frameworks make it difficult to identify agents and processes of change. And yet, these same ‘blind spots’ hold the potential to generate new knowledge. The current paper searches for the unknown in the semi-obscurity of the urban night. This does not imply that nocturnal landscapes are absent, on the contrary, they are territories of distinct appropriations, contestation and reflective agency. Rather, the nightscape offers an alternate regard on the diurnal city, a view that in darkness, requires even greater focus. Exploring Blanchot’s concept of the ‘other’ night as defined in “Le Dehors, La Nuit,” from *L’Espace Littéraire* (1955), provides a means of elucidating limits of alterity within nocturnal darkness. And yet, in search of an actionable alterity, the current research asks if there is not a third, ‘anticipatory’ night, one that situates itself between what Blanchot calls the ‘first’, or knowable night, the realm of sleep and everyday(night) life, and the unattainability of the ‘other.’ It is in this night that moments of possibility are accessed and articulated.

Relevance comes as European cities grow darker to reduce energy consumption and light pollution. At the same time, greater populations are investing the night, imposing questions of how the night city is appropriated, where actions may take place and who may participate in these actions. This proposal fits within a larger, interdisciplinary doctoral research project: “Utopian Nights, Navigating No Place in Nocturnal Urban Landscapes.” A project which, through the practice of nightwalking, seeks to generate possibility within specific atmospheres of the nocturnal European city.

Keywords: Blanchot, night, urban space, walking

INTRODUCTION

If night continues to be bound by day, its borders are increasingly contested, caught between the incursions of diurnal economies and often irreversible costs of over-illumination. The environmental impacts of artificial lighting on human well-being, on the preservation of ecosystems and the depletion of natural resources are well-established. Reducing these impacts involves changing the conversation from a focus on “cities of light” to a more balanced and technologically intelligent focus on sustainable, nuanced cities. This conversation is ongoing in Paris, France, where much of my research is based and where public lighting contracts (including street lighting) are set to expire in 2021. Asking how pedestrians will interpret alternate shadings of their city has become essential.

Closely linked to a near 24-hour illumination is the desynchronization of everyday life, driven by the incessant activity of global economies. In France alone, over 15% of employees work regularly or periodically between the hours of midnight and 5 am.¹ As circadian cycles become increasingly dependent on “the dominant, artificially stretched ‘day’” (Dimmer, Solomon and Morris 2017, 31), the identity and cultural functions of the night come into question. Issues of

nocturnal experience, accessibility and possibility in the context of urban space and its appropriations have incited a growing volume of research. The concerns are multidisciplinary, encompassing the fields of environmental design, geography, sociology and urbanism. They underscore the necessity of studying the urban night in order to mediate the increasing segmentation between the city that rests, plays, works and wanders. As geographer Luc Gwiazdzinski—a contributor to the City of Paris’ 2010 report on the state of the capital’s nights²—points out, the interest from researchers and government authorities to open discussions around the attributes, and indeed the protection of the urban night, reflects a need to come to terms with multiple space-times; to develop the night without creating new conflicts and, to invest in the night, “while conserving some of its mystery” (Gwiazdzinski 2015, 10).

In this paper, I explore the potential of nocturnal spatial practice, and specifically nightwalking to generate possibility in the appropriation and experience of urban space. In allowing for an altered perception of the city, the night operates as both a critique of diurnal imperatives and a resource for divergent practice.

Those who do not sleep, who step outside, into the night, either by choice or necessity, make present the shifting boundaries and illuminated archipelagos³ of a distinctly nocturnal landscape. Navigating along lines of reflective agency and control agendas, the nightwalker expands our knowledge of the urban and moves this new-found insight forward. I look to examples from artists engaged with the urban night, as well as to my own nightwalking experiences, to explore strategies for accessing an actionable alterity. One means of access is found in the approach to the “other” night, as defined by Maurice Blanchot (1982). The project allows a connection to be drawn between the articulation of alterity and the position of “no place” in the nocturnal landscape. No place, understood in the Lefebvrian sense as a non-potentialized place (Lefebvre 1991), is interpreted as the generative site of the “good place,” its counterpart in the utopian metaphor. The nightwalker moves beyond diurnal blind spots to perceive what has, as yet, been too “bright” to be imagined.

In the course of this research project, night walks have been largely practiced in and around Paris. Alternate routes have explored urban centers in The Republic of Ireland, England and The Netherlands, while additional dark sky explorations have led to Svalbard and Southern Texas. They have been practiced in solitude but also in the framework of organized municipal and cultural events (in London and Paris) designed to open the night to a larger population, while tempering apprehensions of darkness.

1. DIVERGENCE IN A DARK NIGHT

1.1. TOWARDS A NEW DARKNESS

Darkness is not essentially neutral, positive, or negative; its power depends on the temporal and spatial contexts in which it is experienced. (Edensor 2017, 179)

Darkness, and the atmospheres it evokes, are determining factors in how social space is navigated at night. Darkness provides not only the background against which “action takes place—it has the agency to alter this action altogether” (Wilkinson 2018, 126). Understanding the character of contemporary darkness becomes all the more critical as European cities, including Paris and London, legislate to reduce nocturnal illumination.⁴ Alongside the well-documented concerns of light pollution, paired with efforts to reduce energy consumption and thus, global warming, is the question of how pedestrians will adapt to darker urban nights. How, can negative conceptions of darkness (insecurity, promiscuity, obscurity) be supplemented by positive qualities, such as intimacy, conviviality (Edensor 2015, 422) and, the more aesthetic or atmospheric character of shadows? And how, can a more “judicious”



Figure 1. Paris, 2 am. A popular street in the Marais district as most businesses conform to regulations by extinguishing storefront lighting. (Author 2019)

(Edensor 2017, xiv) approach to artificial lighting take into account the ecological, cultural, spatial, and temporal needs of specific localities?

In his cultural history, *Nights in the Big City: Paris, Berlin, London, 1840-1930*, Joachim Schlör outlines the struggle between darkness and light to define the “true ‘nature’ of the nocturnal city” (1998, 80). It was a struggle in which darkness would eventually lose out to metaphors of: “light and progress, light and modernity, light and the metropolis” (Schlör 1998, 80). However, as culturally engrained as these metaphors have become—and one can include associations of light and security—darkness was never fully conquered. The semi-darkness that characterizes the contemporary urban night continues to condition our perception of light, particularly the reading of exterior architectural lighting and signage. At the same time, shadow is made visible by light. The relationship of illumination and darkness is not binary but interdependent and perpetually fluid (Edensor 2017; Morris 2011). What is referred to throughout this paper as urban darkness, is in fact a modulation of darkness in light – light from the moon, from buildings, streetlamps, vehicles, and infrastructure, all contributing to the diverse nocturnal atmospheres of the city.

The temptation when discussing experiential and qualitative atmospheres of night is to sentimentalize a time-space where freedom, romance and subversion are readily accessible. This is part of the mythology of the urban night, the night of cinema, detective mysteries and revolution. The reality is that from darkness to seduction, these qualities are always articulated around the incessant activities of consumption, industry, mobility, tourism and urban renewal (Eldridge and Nofre 2018, 3). Certainly, there are instances where the qualitative and the consumable overlap. Images of romantic night-time vistas serve to promote tourism, just as the subversive freedom of underground art and music venues can trigger neighborhood regeneration. Throughout the urban night, the interplay of control agendas and human agency is ever-present. The nightwalker has the ability to traverse, or not, zones of simultaneity and discontinuity, both acting on and being acted upon by the nocturnal city.

Nightwalking does not require an act of transgression, as discussed in Michel de Certeau's "Walking in the City" from *The Practice of Everyday Life* (1988). Possibility can be found along known and accessible streets; streets already transformed by partial darkness and differentiated uses. Of course, De Certeau is operating on a largely diurnal and static city (Morris 2009, 692). While recognizing the existence of innumerable, overlapping paths, there is little push-back to acts of resistance. And there is no apparent differentiation in the wants, needs and identity of his walker (figure 3). In *Exploring Nightlife* (2018), Adam Eldridge and Jordi Nofre reference contemporary, global cities, to present a far greater diversity of nocturnal appropriations.

Class, race, gender, sexuality, disability, religion and age all impact on the ways that we experience the night, if indeed we have access to it at all. To speak of the night only in terms of transgression or fun obscures fundamental questions about for whom it offers such promise and upon whose labour/labor this trope is dependent. (Eldridge and Nofre 2018, 10)

What is perceived as a multiplicity of night spaces is the direct reflection of multiple cultures, identities and patterns of use. In terms of spatial practice, the walker traverses not one night, but many nights, often simultaneously.

1.2. NIGHTWALKING AS RECLAMATION AND APPROPRIATION

Nightwalking is a form of "stretched-out, mobile belonging" (Edensor 2010, 706). As a methodology it allows for a close and tangible enacting on, and by, the city. The act of passing by is never passive, nor is the role of the nightwalker only to observe. From



Figure 2. Montreuil, 4 am. On the roof of Mozinor, a 1970's industrial building. Workspaces are accessed by an interior car ramp leading up to what was meant to be a vast roof garden. Paris' first raves were held on this roof. Music videos have been filmed here. Practices different from the diurnal tenants: model-maker, hosiery manufacturer, and a company that has been painting baby-foot figures for three generations. (Author 2018)



Figure 3. Paris, 1:45 am. The place of a woman walking at night along the Seine reflects that of the author on the bridge above. Gender being one differentiator in nocturnal experience. (Author 2018)

its etymological roots, "nightwalking is 'extravagant,' meaning that it involves wandering beyond bounds, both geographical and social" (Beaumont 2015, 8). The nightwalker has the ability to uncover "practices of urbanism that are not neatly folded into more forceful

stories" (Rossiter and Gibson, 2011), including those of the night-time economy, urban development and consumerism.

The emergent history of the nightwalker parallels the development of street lighting and subsequent "nocturnalization" (Koslofsky 2011, 2) of the city. From the mid-eighteenth century when Nicolas Rétif de La Bretonne, the self-proclaimed *Hibou-Spectateur*,⁵ chronicled the Paris night, to the restless houselessness of Charles Dickens in his London "Night Walks" (1860); to the Surrealist nights of Louis Aragon in *Le Paysan de Paris* (1926), and the auto-reflection of Roland Barthes in "Soirées de Paris" (1979), nightwalking narratives have filled the need to "reclaim, redeem and transform" (Beaumont 2015, 11) the city as one's own. In the current era of 24-hour availability, it is not just the city being reclaimed, but the right to sleep, to rest and to truly go dark.

As Simone Delattre explains, the nightwalker is continually caught in the contradiction of being both "solitary sovereign", unique creator and embodiment of a self-guided city, and "blind subject,"⁶ operating in co-presence with political and economic agendas. There is always the desire to, on one hand, understand the night, and on the other, to be submerged by the "intoxication of the labyrinth" (Delattre 2003, 113). It is this contradiction that attracts artist and narrator to wander the urban night. Night becomes a "trope for the unthought and the unthinkable" (Bronfen 2013, 19), an opportunity to be both in the city and removed from its obligations and expectations.

2. NOCTURNAL POSSIBILITY

2.1. BLANCHOT AND THE OTHER NIGHT

In "The Outside, The Night," from *The Space of Literature*, Maurice Blanchot introduces his concept of the "first night" (*première nuit*) and more elusive "other night" (*l'autre nuit*). Reflecting on the writing of nocturnal darkness, he presents a means of thinking about the night as both true and impenetrable. Writing in the 1950s, Blanchot observes the increasing dissolution of nocturnal elements into the "empire" of the day and the "withdrawal" of night into light (Blanchot 1982, 167). This night is the first night. It is the night that follows the accepted circadian rhythms of sleep and repose. It is the night of darkness, "when everything has disappeared" (Blanchot 1982, 163) and yet, it is a welcoming night, a night we can enter into, lay down in, a night that embraces death.

The "other" night eludes appropriation. It is an abstract night, encountered when what we believed to have disappeared, reappears with new intensity or in another form.⁷ Here the invisible is what one cannot



Figure 4. Paris, 12:42 pm. Le Parc des Buttes-Chaumont was of thirteen Paris parks left open summer nights from June 24 to September 8, 2019. Excepting the move from gas to electric lighting, the parc has not changed since Aragon wrote *Le Paysan de Paris*. (Author 2019)

cease to see; it is the incessant making itself seen (Blanchot 1982, 163). The attraction of the other is the acknowledgement of what Michel Foucault, writing on Blanchot, termed "thought from the outside" (Foucault 1987, 16) or, a chance to view the night as it truly is. But you cannot search methodically. The night attracts by "negligence" (Blanchot 1982, 170). Louis Aragon applies a similar strategy in his Paris night walks, believing in the inherent possibility of error as well as the ability, with "each step" (Aragon 1994, 10), to invent new realities, new modern myths. On one such night walk, in Paris' Parc des Buttes Chaumont,⁸ Aragon experiences a *frisson*, or shiver of expectation, as boundaries dissolve to provide a glimpse of the "other" (Asholt 2009, 165). I have taken this same walk (figure 4). Not in pilgrimage—Aragon's experience cannot be repeated—but for what today is a rare opportunity to visit a Parisian park after dark. And, to see who else on a damp Wednesday night has had the same idea. Amongst manmade hills and paths that end in darkness, I could almost believe the illusion of being in nature, of being outside the city.

For Blanchot, the approach of the other is the approach of impossibility. It is the same impossibility encountered in the act of writing, and by extension, the creative work (*l'oeuvre*). This experience of impossibility "is purely nocturnal, it is the very experience of night" (Blanchot 1982, 163).

2.2. GENERATING ALTERITY

Between restful nights and unfathomable darkness, there remains a terrain of practice in which the nightwalker can not only attempt to approach the "other," but can gain some portion of actionable, outside knowledge. In this, anticipatory time-space, outside knowledge is understood as an opening of critical perspective. With each step, this knowledge is being sketched and schematized (Marin 1984,10) in preparation of a divergent future. To draw a further parallel with utopian thinking,⁹ the nightwalker accepts that "different ways of organizing urban life and space are imaginable and potentially realizable" (Pinder 2015, 30). The traversing of nocturnal space and the potential encounter with no place, not as a void or meaningless place but as a generative site of possibility, requires a mode of walking that is essentially anticipatory. In other words, one that allows for the "contingency of the possible" (Pinder 2015, 31), in order to capture and accept potential.

In his chapter "Night-walking," Schlör reinforces the idea of anticipation. Reflecting on the many "pedestrian investigators" writing the modern nocturnal city, he suggests that if aspects of the urban night "evade the penetrating gaze of systematic research," (Schlör 1998, 269), their eventual, if momentary, unveiling is not accidental. Rather, the nightwalker passes by "in the certain knowledge that the accident will happen" (Schlör 1998, 269). The different identities of the nightwalker and subsequent "ways of walking," (Schlör 1998, 269),enriches this theory. Each augments our knowledge of the city, and most importantly, sets "this knowledge *in movement*" (Schlör 1998, 269). Schlör's thinking recalls Lefebvre's concept of "moments," synthesized by David Harvey in his *Afterward to The Production of Space*:

The 'moment' which he interpreted as fleeting but decisive sensations (of delight, surrender, disgust, surprise, horror, or outrage) which were somehow revelatory of the totality of possibilities contained in daily existence. Such movements were ephemeral and would pass instantaneously into oblivion, but during their passage all manner of possibilities – often decisive and sometimes revolutionary – stood to be both uncovered and achieved. (Harvey 1991, 429)

For Lefebvre, multiple practices within the urban are "full to overflowing with alternative possibility" (Harvey 2013, xvii). "Moments" were seen as instances of rupture, experienced outside of habitual routines and capable of opening a brief view to a transformed world (Pinder 2015, 36). The achievability of the moment, its need to be acted upon, is what enables the generation of possibility. How this generative action can take form, in narrative, in artistic intervention, and integrated within urban practice, is central to the nightwalking project.

2.3. PRACTICING TEMPORAL DIVERGENCE

In her series, *What Is the Shape of This Question?* (1999), Louise Bourgeois asks: "Has the day invaded the night or has the night invaded the day?"¹⁰ Bourgeois, who suffered from insomnia throughout her life, addresses the blurred boundaries of chronological, social, and lived time. The problematic she poses is whether the night is shrinking, encroached upon by diurnal enterprise, or expanding with the endless potential of more time to "do". Sleep is no longer essential to the equation. More often, in these times of continual connectivity, sleep is an act of resistance. It is why, in his book *24/7: Late Capitalism and the Ends of Sleep*, Jonathan Crary, referencing the work of Emmanuel Levinas, distinguishes between insomnia, the watchful vigilance of those too attentive to turn away from the day's realities, and the imposed sleeplessness of round-the-clock production (Crary 2014, 18-19).

Opened in October 2019, a multidisciplinary exhibition entitled "24/7", and directly inspired by Crary's writing, opened at Somerset House in London.¹¹ Artists portray a world where a "premium is placed on activity" (Crary 2014, 15). What remains of "alternate temporalities" (Crary 2014, 19), where it is still possible to live off-the-clock, is investigated by artist and researcher Helga Schmid. Schmid staged *24 Hours in Uchronia*, inviting participants to enter a temporal utopia, removed from traditional time and social structures for one full "night". Once outside of Uchronia and back on the London streets, however, social time retakes control. While temporary, this event along with artist-led night walks, allowed a wider public to think differently about the night. It was also safe, perhaps the primary factor in encouraging, if only occasionally, the public to inhabit the urban night. As I noted at another nocturnal event, a night run organized by the City of Paris,¹² while the elation of traversing the capital, of absorbing the energy of a Saturday night with runners of all ages, speaking multiple languages, stayed with me well after my 3am finish, my mobility was not "normal". Nor was the route, which included access to various monuments, repeatable. However, if I was abdicating much of my personal narrative of the night to the event agenda, I could still pause to witness the palpable emptiness of business districts; and the conversion, even in October, of parks and river quays into extended living rooms. My perception, conditioned by "ingrained, seemingly natural predispositions towards the urban surroundings" (Dunn 2016, 9), began to shift. No longer drawn to the same landmarks as in the day, the backdrop of architecture was made innocuous by the glare of sodium lamps or inversely, gained density in shadow (figure 5). The finish line crossed, I was again left to my solidarity wanderings, to find a way home and see the day rise.



Figure 5. Paris, 11:36 pm. La Grande Traversée opened spaces not normally accessible by night to the public. In shadow above, the Meditation Space by Tadao Ando against Marcel Breuer's landmark UNESCO building. (Author 2019)

2.4. CONTROL AGENDAS AND MEDIATING CIRCUMSTANCES

It has been argued, notably by Robert Williams, that when city authorities sanction cultural appropriations such as light festivals and night markets, they can be seen as exercising a form of counter-agenda designed to reterritorialize (Williams 2008, 516), or take back a night that has escaped control. Certainly, strategies of control exist in many forms. Williams cites the mechanisms of video surveillance (Williams 2008, 518) and the use of electric lighting to “channel” the public along preferred routes (Williams 2008, 522). In parallel, tactics of prohibition, or what Henri Lefebvre calls ‘negative appropriation’ (Lefebvre 1991, 319), are used to make spaces inaccessible to different segments of the population. Physical barriers are erected to signify ownership and thus exclusion. More subtle tactics divide the population by zone (work, entertainment, sleep). Even zones accorded to “the body, sex and pleasure” (Lefebvre 1991, 320) are well defined. Their supposed freedoms only “profitable pseudo-transgressions” (Lefebvre 1991, 320), regulated to designated nightlife districts.

The freedom of individuals to roam the night, to seek out darkness and exercise “reflective agency”

(Williams 2008, 520) is interpreted by Williams as a form of deterritorialization—the counter-use of hegemonic space. In a time when cities are growing darker, where individuals are on the street for other reasons than resistance (work, migration, homelessness), the more pertinent question is how to mediate multiple agendas. Ultimately for Williams, it is the overlapping and often contradictory modes of nocturnal practice that generate what we understand as urban night space (Williams 2008, 526). The perspective of a mediated and contested night space is further elucidated by nightwalking. Traversing a city allows a cross-section of overlapping “nights” and points of contact to be discerned, but not without exposing spatial practice to the influence of darkness and temporal shifts (early evening, deep night, predawn). And it is this ongoing interplay, enacted on and embedded with the distinct built environment of the city, that constructs “assembled” (Shaw 2018, 75) atmospheres of urban nocturnal time-space.

3. NIGHT AS NOT-YET AWAKENED

Throughout this paper, the operation of nightwalking has been presented as a means to engender possibility in the alterity of the urban nightscape. As practice, it ventures on a path towards what Ernst Bloch, in *The Principle of Hope* (1986), located in the “Not-Yet-Become” (Bloch 1986, 6). This nearby potential “exists and is in motion” (Bloch 1986, 4). The Not-Yet-Become night diverges from the present night in that, like hope, it still has to must be learned (Bloch 1986, 3). Therefore, the eventuality of the nightwalker’s arrival becomes just as important as the final destination. Knowledge comes by entering the night and is embodied in the diverse rhythms and modes of walking.

While the “other” night entrances the nightwalker to go beyond the possible, the true potential of the urban night is its nearness. The night is different from the day in terms of social practice, density, visibility and referential perceptions of identity and culture, but it also is able to reflect on the diurnal city. As Gwiazdzinski concludes:

Night brings us back to the essential dimensions of the city and of life: humanity and emotion It is a space-time that allows us to identify the weak signals, the emerging initiatives and indicators of the future-possible city. (Gwiazdzinski 2010, 98)

Studying the urban night adds to an essential comprehension of how cities function including, how they will adapt to greater darkness and larger active nocturnal populations. It is an opportunity to reevaluate the city and its architecture, asking questions of what is a building in darkness, a public square or park? Finally, night provides the possibility of generating as yet unknown solutions.

ENDNOTES

- 1 From the 2012 analysis published in August 2014 by DARES, the internal research arm of the French Ministère d'Emploi. The 15.4 % figure represents 15.3 million French workers, one million more than in 1991. Full report available at <https://travail-emploi.gouv.fr/IMG/pdf/2014-062.pdf>.
- 2 Luc Gwiazdzinski. Introduction to *Les Nuits de Paris. Acts des États Généraux de la Nuit à Paris*. Leonel Sagahon and Fabrizio Léon Directors. Conference Publication. Mairie de Paris, (November 12-13, 2010). <https://drive.google.com/filed/0B7W0fZJICAvFNfQyR1IDcG1dXM/view>.
- 3 See Luc Gwiazdzinski's discussion of archipelagos in "The Urban Night: A Space Time for Innovation and Sustainable Development." *Articulo, Journal of Urban Research*. Special Issue: The Urban Night (November 2015). <https://halshs.archives-ouvertes.fr/halshs-01399557>.
- 4 In France, a 2013 regulation requires commercial and public buildings to turn off interior lights one hour after the last employee has left the building. Exterior illuminated signage is to be turned off from 1am to 6am. See <https://www.service-public.fr/professionnels-entreprises/vosdroits/F24396>. Also see 2018 City of London Lighting Strategy: <https://www.cityoflondon.gov.uk/services/environment-and-planning/city-public-realm/Pages/strategies.aspx>.
- 5 The "Owl-Spectator." Nicholas Rétif de la Bretonne. 1987. *Les Nuits de Paris, ou le Spectateur-nocturne*. (Paris: Gallimard, Folio Classique). Originally written between 1767 and 1788. See also Louis Sébastien Mercier, 1998. *Le Tableau de Paris*. (Paris: La Découverte).
- 6 From the French: "autrement dit d'en être le souverain solitaire ou le sujet aveugle." Simone Delattre. (2013). *Les Douze Heures Noires, La Nuit à Paris au XIX^e Siècle*. (Paris: Albin Michel), 113.
- 7 From the original French; "une autre nuit, où le disparu revient sous une autre forme et avec une nouvelle intensité." Wolfgang Asholt, "Promenades Nocturnes des Surréalistes." *Promenades Nocturnes*. Ed. Alain Montandon. (Paris: L'Harmattan, 2009), 157.
- 8 Louis Aragon. 1986 (1926). "La Sentiment de la Nature aux Buttes-Chaumont." In *Le Paysan de Paris*. (Paris: Gallimard). The English edition is entitled *Paris Peasant*. Translated by Simon Taylor Watson. (Boston: Exact Change, 1994).
- 9 For a better understanding of utopian criticism see, Tom Moylan and Raffaella Baccolini, Eds. (2007). *Utopia Method Vision: The Value of Social Dreaming*. 3rd Edition (Bern: Peter Lang).
- 10 Louise Bourgeois. 1999. "Has the day invaded the night, or has the night invaded the day?" no. 5 of 9 from the series *What Is the Shape of This Problem?* New York: Galerie Lelong.
- 11 24/7. October 31, 2019 to February 23, 2020. Embankment Galleries, Somerset House, London. The presentation of Helga Schmid's *24 Hours in Uchronia*, took place February 7-8, 2020.
- 12 "La Grande Traversée" was organized October 5-6, 2019, as part of the annual Nuit Blanche, or all-night cultural event. See <https://www.paris.fr/pages/une-nuit-blanche-en-mouvement-6889>.

REFERENCES

- Aragon, L. 1986 (1926). *Le Paysan de Paris*. Paris: Gallimard.
- Asholt, W. 2009. "Promenades Nocturnes des Surréalistes." In *Promenades Nocturnes*. Edited by Alain Montandon, 155-170. Paris: L'Harmattan.
- Barthes, R. 1987. *Incidents*. Paris: Éditions du Seuil.
- Beaumont, M. 2015. *Night Walking, A Nocturnal History of London*. London: Verso.
- Blanchot, M. 1955. *L'Espace Littéraire*. Paris: Gallimard, Folio Essais.
- Blanchot, M. 1982. *The Space of Literature*. Trans. by Anne Smock. Lincoln: University of Nebraska Press.
- Bloch, E. 1986. *The Principle of Hope*, Vol. 1. Translated by Neville Plaice, Stephen Plaice and Paul Knight. Cambridge: MIT Press. (Original German publication 1959)
- Bourgeois, L. 1999. "Has the Day Invaded the Night, or Has the Night Invaded the Day?" From the series, *What Is the Shape of This Question?* [Letterpress] Modern Museum of Art, New York.
- Bronfen, E. 2013. *Night Passages: Philosophy, Literature, and Film*. Translated by the Author with David Brenner. New York: Columbia University Press. (Original German published 2008).
- Crary, J. 2014. *24/7, Late Capitalism and the Ends of Sleep*. London: Verso.
- De Certeau, M. 1988. "Walking in the City". In *The Practice of Everyday Life*. Translated by Steven Rendall. Berkeley: University of California Press.
- Delattre, S. 2003. *Les Douze Heures Noires, La Nuit à Paris au XIX^e Siècle*. Paris: Albin Michel.
- Dickens, C. 2010. *Night Walks*. London: Penguin Books. (Originally published in 1860).
- Dimmer, C., Golani Solomon E., and Morris, B. 2017. "1am-5am: Tokyo, Urban Rhythms and The Politics of Train Schedules." *Scapegoat: Architecture, Landscape, Political, Economy* 10. (Winter/Spring): 29-39.
- Dunn, N. 2016. *Dark Matters, A Manifesto for the Nocturnal City*. United Kingdom: John Hunt Publishing.

- Edensor, T. 2010. "Walking in Rhythms: Place, Regulation, Style and the Flow of Experience." *Visual Studies* 10, (March): 69–79. <http://dx.doi.org/10.1080/14725861003606902>
- Edensor, T. 2015. "The Gloomy City: Rethinking the Relationship between Light and Dark." *Urban Studies* 52, no. 3 (February): 422–438.
- Edensor, T. 2017. *From Light to Dark: Daylight, Illumination, and Gloom*. Minneapolis: University of Minnesota Press.
- Ekirch, R. 2005. *At Day's Close: Night in Times Past*. London: W. W. Norton and Company.
- Foucault, M., 1987 (1997). "Maurice Blanchot: The Thought From Outside." *Foucault/Blanchot*. Translated by J. Mehlman and B. Massumi. New York: Zone Books.
- Gwiazdzinski, L. 2005. *La Nuit, Dernière Frontière de la Ville*. Paris: Editions de l'Aube.
- Gwiazdzinski, L. 2010. Introduction to *Les Nuits de Paris: Acts des États Généraux de la Nuit à Paris*. Conference publication. L. Sagahon and F. Léon, Directors. Mairie de Paris (November 12-13). <https://drive.google.com/filed/0B7W0fZJICAvFNfQyR1DcG1idXM/view>.
- Gwiazdzinski, L. 2015. "The Urban Night: A Space Time for Innovation and Sustainable Development." *Articulo, Journal of Urban Research*. Special Issue: The Urban Night (November). <https://halshs.archives-ouvertes.fr/halshs-01399557/document>.
- Harvey, D. 1991. Afterword to *The Production of Space*. Written by Henri Lefebvre, 425-431. Oxford: Basil Blackwell.
- Harvey, D. 2013. *Rebel Cities: From the Right to the City to the Urban Revolution*. London: Verso.
- Jalón Oyarzun, L. 2017. "Night as Commons, Minor Architecture and Dayfaring Citizens." *Scapegoat: Architecture, Landscape, Political, Economy* 10. (Winter/Spring): 57-70.
- Kofman, E. and E. Lebas, E. 1996. "Lost in Transposition: Time, Space and the City." In *Writings on Cities: Henri Lefebvre*. Edited and Translated by E. Kofman and E. Lebas, 1-60. Oxford: Blackwell Publishing.
- Koslofsky, C. 2011. *Evening's Empire, A History of the Night in Early Modern Europe*. Cambridge: Cambridge University Press.
- Lefebvre, H. 1991. *The Production of Space*. Translated by Donald Nicholson-Smith. Maldon: Blackwell Publishing. (Original French publication 1974).
- Lefebvre, H. 2003. *The Urban Revolution*. Translated by Robert Bononno. Minneapolis: University of Minnesota Press. (Original French Publication 1970).
- Levitas, R. 2011. *The Concept of Utopia*. Oxford: Peter Lang.
- Marin, L. 1984. *Utopics: Spatial Play*. London: Macmillan.
- Melbin, M. 1978. "Night as Frontier." *American Sociological Review* 43, no. 1: 3-22. <https://doi.org/10.2307/2094758>
- Mercier, L-S. 1998. *Le Tableau de Paris*. Paris: La Découverte.
- Montandon, A., ed. 2009. *Promenades Nocturnes*. Paris: L'Harmattan.
- Morris, B. 2004. "What We Talk About When We Talk About Walking in the City." *Cultural Studies* 18, no. 5 (September): 675-697.
- Morris, N. 2011. "Night walking: Darkness and Sensory Perception in a Night-time Landscape Installation." *Cultural Geographies* 18, no. 3: 315–342.
- Moylan, T. and Baccolini, R., eds. 2007. *Utopia Method Vision: The Value of Social Dreaming*. 3rd Ed. Bern: Peter Lang.
- Nofre, J. and Eldridge, A., eds. 2018. *Exploring Nightlife: Space, Society and Governance*. London: Rowman & Littlefield.
- Pinder, David. 2001. "Ghostly Footsteps: Voices, Memories and Walks in the City." *Cultural Geographies* 8, Issue 1 (January): 1-16.
- Pinder, DDavid. 2015. "Reconstituting the Possible: Lefebvre, Utopia and the Urban Question." *International Journal of Urban and Regional Research* 39, Issue 1 (January): 28-45.
- Rétif de La Bretonne, N. 1987. *Les Nuits du Paris, ou le Spectateur-nocturne*. Editors Jean Varloot and Michel Delon. Paris: Gallimard, Folio Classique.
- Roberts, M. and Eldridge, A. 2009. *Planning the Night-time City*. Oxon: Routledge.
- Rossiter, B. and Gibson, K. 2011. "Walking and Performing, 'The City': a Melbourne Chronicle." In *The New Blackwell Companion to The City*. Eds. G. Bridge and S. Watson, 488-498. London: Wiley-Blackwell.
- Sandin, Gunnar. 2003. "Dealing with non-place in exploitation, belonging and drifting." *Nordisk Arkitekturforskning* 16, no. 2: 67-85.
- Schivelbusch, W. 1995. *Disenchanted Night: The Industrialization of Light in the Nineteenth Century*. Translated by Angela Davies. Berkeley: University of California Press. (Original German publication 1983).
- Schlör, J. 1998, (2018). *Nights in the Big City: Paris, Berlin, London 1840-1930*. Translated by Pierre Gottfried Imhof and Dafydd Rees Roberts. London: Reaktion Books.
- Shaw, R. 2014. "Beyond Night-Time Economy: Affective Atmospheres of the Urban Night." *Geoforum* 51 (1): 87-95.
- Shaw, R. 2015. "Night as Fragmenting Frontier: Understanding the Night That Remains in an Era of 24/7." *Geography Compass* 9, no. 12: 637–647.

Shaw, R. 2018. *The Nocturnal City*. London: Routledge.

Stone, T. 2018. "The Value of Darkness: A Moral Framework for Urban Nighttime Lighting", *Science and Engineering Ethics* 24, no. 2: 607-628. <https://doi.org/10.1007/s11948-017-9924-0>.

Wilkinson, S. 2018. "Young People, Alcohol and Suburban Nightscapes." In *Exploring Nightlife: Space, Society and Governance*. Edited by Jordi Nofre and Adam Eldridge, 114-128. London: Rowman & Littlefield.

Williams, R. 2008. "Night Spaces: Darkness, Deterritorialization and Social Control." *Space and Culture* 11, no. 4 (November): 514-532. <https://doi.org/10.1177/1206331208320117>.

A SUSTAINABLE ALTERNATIVE TO ARCHITECTURAL MATERIALS: Mycelium-based Bio-Composites

Ali Ghazvinian
Pennsylvania State University

Abstract: In the history of architecture, technologies adapted from other disciplines have created new paradigms for design and production. During the first Industrial Revolution, for instance, developments in mechanical and material engineering, and the introduction of wrought-iron, steel, and concrete, led to revolutionary changes in architecture. In the nineteenth and twentieth centuries, electrical engineering and electronics had a similar groundbreaking effect on architecture and design. It seems that regarding the necessities and problems that exist in the 21st century, such as dependency on fossil fuels for construction that lead to carbon emission, the abundance of solid and liquid waste and unjustifiable costs, another change in the paradigm of construction is required. One possible way to address these issues is to return to nature and take advantage of biomaterials. This research studies the integration of mycelium-based bio-composites into the field of architecture. Mycelium is the vegetative part of mushrooms by which they absorb nutrients from the soil. When treated, mycelium results in a foam-like composite material that is lightweight, and biodegradable. Over the past couple of years, designers started to use mycelium-based composites in several applications ranging from product design and furniture to building panels and masonry blocks. In this research, the aim is to explore novel methods to use mycelium-based bio-composites in temporary and/or low-rise constructions. The focus of the research is on enhancing the material properties by investigating the factors that affect the nature and growth of the cultivated mycelium-based bio-composites and exploring novel structural systems based on the constraints and affordances of mycelium-based bio-composites, using computational form-finding techniques, generative design and optimization methods. In this paper, the initial incentives for conducting the research and the proposed methodology are discussed.

Keywords: Biomaterials, bio design, mycelium, bio-composites, masonry

INTRODUCTION

Material thinking is important for architecture, as it is through materials that design ideas are converted to physical artifacts. This process requires accessible, cost-effective and sustainable solutions. The industrialization of materials initiated three revolutionary changes in architecture during the last centuries, towards a less sustainable building industry. In the 18th century, the invention of the steam engine allowed people to use machines as their agents for the industry. During the last decades of the nineteenth century, the use of electrical power initiated a second change, and in the mid-twentieth century, the invention of computers and digital technologies revolutionized the industry for the third time (Hebel and Heisel 2017). After the industrial revolution, the main structure of buildings changed from masonry to steel frame after mass production of materials, such as concrete and steel, afforded the possibility to raise taller buildings thanks to the invention of mechanical tools like pumps and elevators.

Industrial solutions for architecture, engineering and construction (AEC) cannot change the method of thinking and only modify traditional ways temporarily. They may provide a remedy for problems of the

current century such as air pollution, global warming and landfill waste. However, architecture requires a shift to be reactive and to adapt to the environment. Materials, as the backbone of the AEC industry, would play a critical role in this shift. The current approach of production, utilization and disposal can be shifted to production, utilization, recycling and reutilization. Nature provides optimal and sustainable answers using limited resources. Therefore, researchers from biology, material science, as well as designers and architects can collaborate to explore ways to convert materials from nature to the building industry for more sustainable alternatives.

This paper first presents a background study on biomaterials in architecture, specifically focusing on mycelium and its applications in design and architecture. Then, the proposed methodology for the Ph.D. study to integrate mycelium-based bio-composites to architecture is presented.

1. BIOMATERIALS

1.1. BIOMATERIALS IN ARCHITECTURE

Park and Bechthold (2013) suggest that the fourth revolutionary change in the building industry may

A Sustainable Alternative to Architectural Materials

happen soon with a return to nature. According to Flynn (2016), such a shift in architecture, to what she calls "living architecture" requires modern thinking and technologies. Nature's answer to the problem of materials is the use of biomaterials. Biomaterials are materials derived from living organisms whose mechanical properties are often outstanding, in comparison to the weak constituents from which they are assembled (Zolotovskiy 2018). These materials are generally sustainable because they use little amount of energy to perform their function and produce the least amount of waste (Vincent 2012). However, there are some challenges for utilizing biomaterials in the building industry: They require processing, as many of them cannot be used as raw materials, and their large-scale applications are still underdeveloped (Derme et al. 2016). To develop biomaterials for the built environment, novel technologies that can enhance their properties with the least modification needed in their natural behavior are required. The methods used for developing matter to be used as bio-based materials are different: some require ordinary processes such as baking, molding and mixing, while others will require more radical ones like cultivating, breeding, raising or farming (Hebel and Heisel 2017). Girometta et al. (2019) consider materials that contain at least one component that is biologically produced and that are completely biodegradable as bio-based composites (Girometta et al. 2019). These materials are usually durable, with superior mechanical properties, generated by "soft living tissues" (Zolotovskiy 2018). The most important features of biomaterials are their multifunctionality, hierarchy, and the ability to self-assemble and self-heal. Motivations to integrate bio-based materials with design and architecture arise from the fascinating opportunities for diverse forms of expressions that can be achieved, and the possibility to reimagine the paradigms of production towards more sustainable solutions (Karana et al. 2018).

1.2. CLASSIFICATION FOR BIOMATERIALS

Materials in this area can be categorized according to their operating system. Some materials are used in the process of fabrication and when the project is finished, they are killed or at least, hibernated. The other set of materials respond to the environment after the production and behave as a part of the living body and an element of final architecture. The last group is the ones that are full of living organisms interacting with the environment and reacting with stimuli, activating the architecture completely. In literature, these three groups are called "bio-based materials", "bio-responsive materials" and "bio-active materials," respectively (Zolotovskiy 2018; Lu et al. 2016). For example, bacterial cellulose (figure 1-A), crustacean-

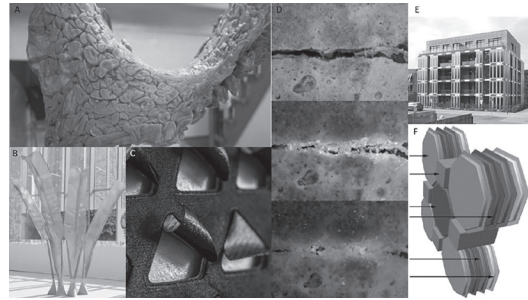


Figure 1: A. Structure made of bacterial cellulose (Derme et al., 2016), B. Structure made of crustacean polysaccharides (Mogas-Soldevila et al., 2015) C. Sweat-reacting bio-actuators (<http://digicult.it>), D. Self-healing bio-concretes (Delft University), E. BIQ house (<http://thenextgreen.ca>) and F. Water walls concept (Cohen, Flynn, and Matossian 2012)

based polysaccharides (figure 1-B) and wood foam can be mentioned as instances for "bio-based materials." Living bio-actuators (figure 1-C) and self-healing Bio-concretes (figure 1-D) are examples of "bio-responsive materials." BIQ House (figure 1-E) and PBR façade that use algae in their envelope, Living Architecture blocks and Water Walls (figure 1-F) that use microbes and algae to purify air and water and to generate electricity, fall into the category of "bio-active materials."

2. FUNGAL SOLUTION

One of the natural matters that can be cultivated and can substitute current construction materials is mycelium-based bio-composites. Mycelium is the root network of fungi, a fast-growing matrix that acts as a natural binder consisting of *hyphae*. It consumes organic waste and produces biodegradable bio-composites. Mycelium-based bio-composites have been explored particularly to produce new materials for packaging, thermal and acoustic insulation and a broad variety of design objects and furniture. Scholars from several disciplines, such as mechanical and industrial engineering, industrial design, chemistry, and biology, have conducted research on this new material, however, there is little literature on the use of mycelium-based bio-composites in the AEC industry. The purpose of current research is to assess the abilities of mycelium and the opportunities it offers for conversion to the architectural context as a building material, and to define frameworks for using this new bio-derived material in this field.

2.1. MYCELIUM

Mycelium is the vegetative part of fungi made of a mass of hyphae. Hyphae is the long, branching filamentous structure, acting as the growth agent in fungi. Each hypha consists of one or more cells which advance the

growth process by division and has an average diameter of 4-6 micrometers. Mycelium, with enzymes secreted from hyphae, break down the biopolymers to simpler bodies and then absorb them by active transport, which is an action at the cellular scale of living organisms to digest carbon-based nutrients. This process lets the hyphae grow out of the substrate into the air, creating a “fluffy or compact layer covering the substrate, called fungal skin” (Appels et al. 2019). Thus, fungal colonies made of mycelium can be found inside or on the surface of organic substrates such as soil, sawdust, paper and any other carbon-based matter. The primary uses of mycelium in nature are related to its ability to decompose organic waste, due to the existence of carbon in organic matter.

The filamentous mode of growth in mycelium leads to colonization of substrates and provides a large surface to volume ratio resulting in better uptake of nutrients. Complex structures in organic waste such as wood, straw, and hemp must be degraded into smaller and simpler ones, before being able to be taken up to serve as an energy source. For this purpose, fungi, through the hyphae, secrete a multitude of enzymes (Wösten 2019). This feature of mycelium enhances biodegradability. This is of high importance for industrial production. In the current era, with rapid population growth, intensified agriculture, and industrialization fast and low-cost manufacturing processes lead to constant growth of production, consumption, and accumulation of waste. Alternative building materials that are biodegradable and derived from renewable resources are valuable (Attias et al. 2017), and mycelium is a potential alternative.

2.2. MYCELIUM-BASED MATERIALS

There are two main groups of mycelium-based materials: Pure mycelium and mycelium-based bio-composites. Pure mycelium is the result of complete degradation of the substrate. It is also obtainable by “removing the fungal skin from the substrate” (Appels et al. 2019). Mycelium-based bio-composites, on the other hand, are the result of hibernation or killing of mycelium in its growth process. During colonization of the substrate, fungal growth can be stopped by drying or heating the material. Drying the mycelium, leads to its hibernation which means the fungi is ready to restart growth when environmental conditions allow it and heating will stop the fungi growth permanently. The result of either of these processes is a mycelium-based bio-composite. During the growth process, the fungus cements the substrate, which is partially replaced by the tenacious biomass of the fungus itself. Composites can be shaped to produce insulating panels, packaging materials, bricks, or new-design objects (Girometta et

al. 2019). The properties of both pure and composite mycelium are dependent on the fungal species, substrates, growth conditions, processing of material, and the additives (Jones et al. 2017; Appels et al. 2019).

Existing literature about the tests conducted on the mycelium-based materials (Appels et al. 2019; Bruscatto et al. 2019; Sun et al. 2019; Ghazvianian et al. 2019; Zhang et al. 2019; Yang et al. 2017; Attias et al. 2017; Haneef et al. 2017; Islam et al. 2017) shows how the conditions of cultivation, hibernation/killing, molding, and the characteristics of species and substrates used to affect the results. The consensus about the characteristics of mycelium-based materials is that they have a relatively low density compared to plastics, relatively low compressive strength compared to conventional masonry materials, lack of strength in tension and dependency on the curing process for durability and appearance. The most important feature of this material is its biodegradability. This feature allows the mycelium to fulfill the principle of the circular economy, which requires waste materials to re-enter into a production process rather than being discarded, and the final product must be combustible or compostable (Girometta et al. 2019).

2.3. MYCELIUM-BASED MATERIALS IN INDUSTRIES

Mycelium has been used for more than a century as versatile and highly productive cell factories. It means; they are used to produce enzymes and small molecule compounds, such as antibiotics and organic acids (Wösten 2019). Early explorations in the use of fungi as biomaterials began during the 1990s by the Japanese scientist Shigeru Yamanaka, who explored using mycelium to produce paper and building materials (Girometta 2019). Then, Stamets (2005) proposed using mycelium to filtrate and purify soil and water from microorganisms and chemicals by mycelial mats. In recent years, scholars and industrial teams started using mycelium in product design, fashion, and architecture.

Companies MycoWorks¹ and Mogu², using pure mycelium, started to produce synthetic leather to replace animal leather for sustainable purposes (figure 2-A). The synthetic leather derived from mycelium is flexible, durable and waterproof, and thus can be used to form several shapes such as belts, shoes, wallets, and other accessories in fashion the context. Ecovative³, the first start-up company (established 2007) designated to research the utilization of mycelium in industry, in a collaboration with Dell⁴ and some wineries around the US, started to produce cushions of mycelium to protect hardware and wine bottles in their delivery services to reduce the impact of plastic packaging on the environment (figure 2-B). The project, “Future of Plastics”

A Sustainable Alternative to Architectural Materials



Figure 2: A. Synthetic mycelium-based leather (<http://mycoworks.com>), B. Mycelium-based foam packaging (<http://ecovative.com>), C. Mycelium-based kitchenware (<http://corpuscoli.com>), D. Mycelium-based furniture (<http://ericklarenbeek.com>), E. Mycelium-based furniture (<http://thisisalive.com>) and F. Mycelium-based vases (blast-studio.com)

by Officina Corpuscoli⁵, proposed utensils made of mycelium to be used and then biodegraded (figure 2-C). Living Studio⁶ proposed using mycelium to cultivate fungal cutlery, as a substitute for disposable plastic cutlery, that can be composted after use. Companies like Krown⁷, Terreform One⁸, Balst studio⁹ and GenSpace¹⁰ started to produce light, and biodegradable furniture using mycelium-based bio-composites. Product designers Phil Ross, Erik Klarenbeek, and Jonas Edvard also make use of mycelium as part of their furniture designs (figure 2-D, E, F).

Regarding the characteristics such as efficient insulation performance, fire-resistance, and air purification, mycelium-based materials are proposed to replace chemical, petroleum-based materials used for insulation in buildings (figure 3-A). Companies Mogu and Biohm¹¹ are pioneers in this path. They argue that their method can reduce the environmental impact of the construction process and carbon footprint. Mogu introduced wall and ceiling panels with mycelium, that are either bare or covered by resin-like coatings to be used as insulators on the building envelope.

Beyond the mentioned uses of mycelium material, efforts have been made to also use mycelium as *skeleton* in architecture. One of the most well-known works in architecture where mycelium is used as a building material, is the Hy-Fi Tower designed by David Benjamin from Living Studio¹² and engineered by ARUP¹³ (figure 3-B). The tower, designed and built as part of MoMa PS1 2014, was 13 meters in height. It was made from approximately 10000 mycelium bricks that were derived from the fungal products of the company Ecovative. After hosting events in MoMa PS1 2014 for three months, it was disassembled, broken and mixed with soil to be composted. This project shows the durability, resistance and workability of mycelium. Phil Ross, an artist from MycoWorks,

in his Mycotecture pavilion (figure 3-C), also used mycelium-based bio-composites as bricks. The pavilion is small-scale, and functions as a teahouse. In another project, Block Research Group¹⁴ designed and built MycoTree, a spatial branching structure, using mycelium-based bio-composites (figure 3-D) that were shaped using special molds designed by a 3D graphic statics method. The intention in this project was to find forms that allow the material to bear compression-only loads because mycelium-based bio composites have better load bearing capacity in compression. In other words, using computational form-finding methods, they compensated weaknesses of the material for structural use (Hebel and Heisel 2017). The pavilion was designed for the 2017 Seoul biennale of architecture and urbanism. The Shell Mycelium by Yassin Areddia and Beetles 3.3 was another effort to use mycelium for designing and building a pavilion (figure 3-E). Their intention was to show mycelium as a reliable substitute for concrete in small-scale and temporary construction projects. Pointing on unused stadiums and pavilions built by concrete for events such as exhibitions and Olympics, they designed and built the pavilion for Kuchi Muziris Biennale 2016 in India. In another innovative application with mycelium, modular columns were designed and cultivated (figure 3-F). Also, minimal surfaces were formed by mycelium cultivation (figure 3-G). These experiments were proposed to explore the formal possibilities for mycelium-based materials (Gruber and Imhof 2017).

More recently, Perkins and Will Research Group¹⁵, in their Tactical Mycelium exploration (figure 3-H), inspired by the Tactical Urbanist's Guide to Materials and Design, both borrowed the organic, iterative process of these projects and offered mycelium as "an alternative biomaterial for the future tactician's palette". Inspired by Antoni Gaudi's technique to build catenary arches, Carlo Ratti¹⁶, in collaboration with Krown Biolab researchers, has grown a chain of 60 four-meter-tall arched structures with mycelium for the Milan Design Week (figure 3-I). These arched structures were grown in a six-week period to construct an archway around the Orto Botanico di Brera botanical garden in Milan and after the exhibition, were shredded and added to the soil as compost. Lastly, the Growing Pavilion (figure 3-J), designed by Pascal Leboucq in collaboration with Erik Klarenbeek as an event space is constructed with biomaterials. Among these materials, the external façade is made of panels grown from mycelium. The panels are attached to the timber frame of pavilion and can be removed and repurposed after utilization.

The studies, tests, and experiments on mycelium are currently in advance to explore other opportunities this natural material can offer for a better environment



Figure 3: A. Mycelium-based wall panels (<http://mogu.com>), B. Hy-fi tower (<http://arup.com>), C. Mycotecture Alpha teahouse (<http://glasstire.com>), D. Mycotree pavilion (<http://block.arch.ethz.ch>), E. Shell Mycelium pavilion (<http://asianpaints.com>), F. Mycelium-based columns (Gruber and Imhof, 2017), G. Mycelium-based minimal surface (Cruber and Imhof, 2017), H. Tactical Mycelium monolithic structure (<http://jdovaults.com>), I. The circular garden (<http://carloratti.com>) and J. Growing pavilion (<http://thegrowingpavilion.com>)

and future. The most important part of work with mycelium is to find out how mycelium-based materials' mechanical and chemical properties can be enhanced, and how they perform in long-term use, especially in an architectural context, under potential fatigue and humidity threats.

3. PROPOSED STUDY

In this research, the aim is to explore novel methods for using mycelium-based bio-composites in temporary and/or low-rise constructions as potential substitutes for conventional masonry construction materials. Based on the existing literature, in order to use mycelium-based bio-composites as alternative construction materials, their load-bearing capacity needs to be improved. This can be achieved by two different approaches. The first approach is to enhance material characteristics of mycelium-based composites through material cultivation processes and the second is to design structural systems based on the constraints and affordances of mycelium-based bio-composites using computational form-finding techniques, generative

design, and optimization methods.

The first part of this research investigates the role of growth process for enhancing material features. Since material properties of mycelium-based composites depend on several factors, including the species of fungi and types of organic substrates used in cultivation, time and environmental conditions of growth, and the way its growth is ceased, a series of systematic tests is planned to analyze mechanical strength, in addition to the durability and environmental stability of the cultivated samples. Several samples of mycelium-based composites will be cultivated to identify the growth parameters that have a direct effect on the load-bearing capacity of the composites.

In the second part of the research, the aim is to develop digital models for compression-based structural systems based on the constraints and affordances of mycelium-based bio-composite samples that are cultivated. Using computational structural form-finding (i.e. thrust network analysis, 3D graphic statics, generative shape grammars) and simulation methods (i.e. finite element analysis), the aim is to design and cultivate/fabricate/build a series of physical prototypes in various scales using mycelium-based bio-composites and advanced computer-aided manufacturing technologies.

4. METHODOLOGY

4.1. CRITICAL REVIEW OF LITERATURE

The initial step in order to define methodology is to study the literature. A critical review is needed to identify the nature of the material and the characteristics that make it suitable for architecture. The works done in other disciplines such as mechanical and industrial engineering, industrial design, and biology, as well as design projects that use mycelium-based materials are studied. In addition, the literature related to the techniques used in architectural prototyping, design and making approaches, strategies for integrating new materials to architecture and their ability to be used for mycelium-based bio-composites are reviewed. The review resulted to define a framework for the research.

4.2. FRAMEWORK

Since biomaterials are made of living agents, both the cultivation process and the outcome are not fully predictable (Karana et al. 2018). To tackle this uncertainty, in parallel to the fulfillment of the requirements of a material, a feedback loop is needed. The feedback loop allows the researcher to cope with uncertainty. In order to explore the use of new materials in an architectural context, a recursive study among different parts of the research is necessary because 1) material explorations will inform form-finding and

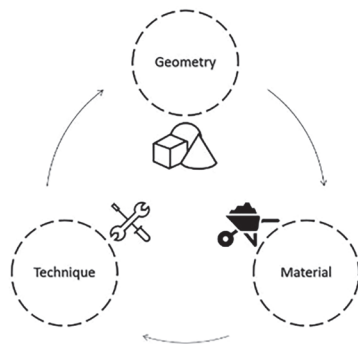


Figure 4: Trifold cycle of recursive study. (Author 2019)

simulation, and 2) changes in the material production may be necessary to improve material properties based on the findings of form-finding, simulation and prototyping stages.

The method of research can be illustrated by a three-stage cycle including material study, fabrication technique and geometric form-finding process (figure 4). This recursive process generates several alternatives for using a specific material with a technique to design a form and produces options for evaluation. By studying the material, the initial properties can be assessed, leading to identify the techniques capable of being used for the material and geometries that are possible. Then, in the fabrication stage, some more properties can be shown, such as workability. The results of fabrication addresses the pros and cons of the material, so it can be enhanced for better utilization and more design and manufacturing options.

4.3. MATERIAL EXPLORATION

The first stage of the research is material exploration. According to the nature of mycelium, the material study consists of the cultivation process and physicochemical, mechanical and environmental experiments. Several parameters in the cultivation process of mycelium-based bio-composites affect the product properties, such as species, substrates, supplements, environmental conditions, and curing processes (figure 5). In the material exploration stage, by systematically changing these parameters and conducting experiments, the desired material alternatives can be explored. One important remark about this stage is that while existing literature is informative, their results are not reliable enough for architectural use. Therefore, conducting material experiments is one of the crucial parts of the methodology.

Species of fungi used in cultivation directly influence the features of the product and the time and conditions of cultivation. More than 30 species of fungi

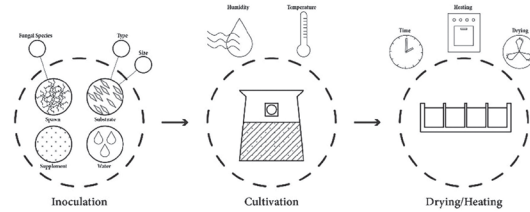


Figure 5: Influencing factors on mycelium-based bio-composites growth (Ghazvinian et al. 2019)

have been studied by scholars for producing mycelium-based materials, pure or composite, in recent years. The most influential factors for choosing the species are their availability, their growth rate, and their growth type. As a sustainable substitute for conventional materials, one of the most important factors for this material is its local availability. Transferring mushroom spawns for growing non-local species is not ideal, as there are two potential problems, namely contamination and change in the growth process due to changing the environment. Other factors related to the growth process are significant, as they optimize the time of cultivation and the texture and density of the product. For example, different hyphal types in fungi by which the species exhibit different systems of branching, lead to different structures for mycelium-based bio-composites.

The type and structure of substrates, the main part of the composites, affect the physicochemical and mechanical properties of the outcome. Substrates provide nutrition for fungal growth: The richer the substrate, the better the outcome of cultivation process. Again, one of the main criteria in choosing substrates is their availability and accessibility, without harming other industries. Researchers in this area have studied the effect of type, size and differences between dense and loose packed substrates on the characteristics of mycelium-based bio-composites. One other effective factor is the additives used with the substrate. Adding fibers to reinforce the substrate or nutritious supplements for increasing the amount of carbon and nitrogen for growth are instances of additives. Like the mixtures for concrete, mixture of mycelium species, substrate, water and the nutrient chosen for feeding the mycelium can change the features of mycelium-based bio-composites.

Environmental conditions of cultivation need to be studied as well, since it is crucial for changing the scale of production. To cultivate an integrated composite, with no fruiting bodies and empty cores, controlled conditions are needed. In smaller scales, chambers can provide a controlled environment, however, in larger scales, to build bigger blocks or monolithic structures for instance, a large-scale controlled environment is needed. The amount of light, humidity, temperature and

existence of contaminant agents need to be controlled.

The drying/heating step and the curing method are also of high importance to the properties of the outcome. The length of the drying/heating process influences the degree of growth for mycelia, affecting the density and texture of the outcome. Pressing the composite, either cold or hot, increases the density and probably the compressive strength of the product. The finishing of the product is also affected by this step of the work, white-rot fungi produce white products that, after pressing, may change to a gradient of grey to brown.

In the material exploration stage, experiments for identification of mycelium-based bio-composites as an architectural material can be divided into four major categories:

1. **Physiochemical properties:** Chemical structure, density, buoyancy, pH, finishing color, and other physical and chemical attributes of the material, which let the designers know the extent of the environment in which this material can be used and narrow down the line of research. Methods such as thermogravimetry, scanning electron microscopy (SEM) and Fourier-transform infrared stereoscopy (FTIR) have been used to explore the structure of the materials produced by mycelium. Studying the composition of materials informs the study about the extents of application and the competitors of the product in different industries.
2. **Mechanical properties:** Compressive, tensile and flexural strength tests of the material are required in order to determine design and fabrication approaches. In the case of using mycelium-based bio-composites as load-bearing elements in architecture, considering their low tensile strength, only compressive structures can be built. In order to use mycelium-based bio-composites in other ways, reinforcement is needed.
3. **Durability:** There is little data about the durability of mycelium-based material in the literature. As a construction material, the applicability of mycelium-based bio-composites in different environmental conditions needs to be evaluated. Conducting experimental work and efforts to improve the durability of mycelium-based bio-composites, which is highly dependent on humidity, will enhance the domain of utilization of this bio-based material.
4. **Insulation:** In addition to the acoustic properties of mycelium-based bio-composites, heat and electric conductivity can be utilized as an important feature in their architectural use, due to the potential insulation agency. Because of their porous nature, mycelium-based bio-composites can be used as insulation.

Some of the fungal species, by creating the fungal skin, enhance the composites in fire retardancy as well, which is another positive potential for a material to be used in the building industry.

4.4. FABRICATION TECHNIQUES

In the next part of the recursive work, techniques able to be used for designing with mycelium-based bio-composites needs to be tested. Simulation and fast prototyping using computational tools and parametric software, and then physical models and prototyping, are required for this stage. The design process is an iterative process, and prototyping allows the designer to assess the results. After initial evaluations through computer simulations, physical explorations are conducted. Several approaches for making use of the new material, such as molding, aggregation, 3D printing, and laser-cutting, can be explored in order to utilize the material in the making processes. It is important to identify possible fabrication techniques for mycelium-based bio-composites and the opportunities that each of them offers for the making process.

4.5. GEOMETRY DESIGN

The other part of the cycle is the form-finding process. This stage is related to the other two parts of the cycle. The results of material exploration and the possible fabrication techniques for mycelium-based bio-composites influence the forms that can be produced. For example, using 3D graphic statics as a technique must be accompanied by using its own form-finding methods. Likewise, some materials, by their features, follow specific grammars that can be extracted by shape grammars and be used for form-finding. Thus, the outputs of other stages are required for starting form-finding and the results from this stage can feed the next cycle of material study. For instance, monolithic geometries may need more material tinkering and exploration since in large-scale moldings, curing by pressing the material is not as simple as curing in aggregation methods, since the greatest structural performance of the material is dependent on the thickness of fungal skin. In order to have more uniform mycelium-based bio-composites cores cemented by hyphae as well as skins, more studies are needed.

This recursive method of material exploration, study of techniques, and geometry design must be applied several times. This research proposes to scale-up the designed geometry in each stage from a micro-scale prototype to meso-scale ones, with macro-scale as one of the final outcomes.

CONCLUSION

The main purpose of this study is to integrate mycelium-based bio-composites to the architectural context as an alternative for conventional masonry materials to be used in low-rise/temporary constructions. Mycelium-based materials are advantageous as a sustainable material due to their green production that uses wastes from other industries to generate materials. They also do not produce waste after demolition, since they are biodegradable. Some other advantages of the material are its light weight, insulation capacity and fire retardancy. The methodology for the conversion has been explained as a recursive method simultaneously exploring material properties, fabrication techniques, and form alternatives. This needs an interdisciplinary approach from computational design, biology, engineering, and materials science disciplines. Based on

the existing literature and the experiments completed, the load-bearing capacities of mycelium-based bio-composites need to be enhanced, either by improving their inherent characteristics via the material cultivation process or by employing structural systems, forms, and geometries that can compensate for these constraints in structural behavior. In the next stages of research, these two approaches will be studied.

ACKNOWLEDGEMENTS

The author acknowledges feedback and support from Dr. Loukas Kalisperis, Dr. Andrew Cole, Dr. Gretchen Kulda, Dr. Maria Jimenez Gasco, Dr. John A. Pecchia, and Dr. Benay Gursoy (author's Ph.D. advisor) for the conceptualization of the work. Support from Paniz Farrokhsiar, Fabricio Vieira, and Dr. Ali Memari during the experimental part of the work is also appreciated.

ENDNOTES

- 1 <http://mycoworks.com>
- 2 <http://mogu.bio>
- 3 <http://ecovatedesign.com>
- 4 <http://dell.com>
- 5 <http://corpuscoli.com>
- 6 <http://livinstudio.com>
- 7 <http://krown.bio>
- 8 <http://terraform.org>
- 9 <http://blast-studio.com>
- 10 <http://genspace.org>
- 11 <http://biohm.co.uk>
- 12 <http://thelivingnewyork.com>
- 13 <http://arup.com>
- 14 <http://block.arch.ethz.ch>
- 15 <http://perkinswill.com>
- 16 <http://carloratti.com>

REFERENCES

- Appels, Freek V. W., Serena Camere, Maurizio Montalti, Elvin Karana, Kaspar M. B. Jansen, Jan Dijksterhuis, Pauline Krijgsheld, and Han A. B. Wösten. 2019. "Fabrication Factors Influencing Mechanical, Moisture-and Water-Related Properties of Mycelium-based Composites." *Materials & Design* 161: 64-71.
- Attias, Noam, Ofer Danaï, Nirit Ezov, Ezri Tarazi, and Yasha J. Grobman. 2017. "Developing Novel Applications of Mycelium Based Bio-composite Materials for Design and Architecture." *Proceedings of Building with Biobased Materials: Best practice and Performance Specification*, 6th–7th (September): 76-77.
- Bruscato, Cláudia, Eloane Malvessi, Rosmary Nichele Brandalise, and Marli Camassola. 2019. "High Performance of Macrofungi in the Production of Mycelium-Based Biofoams Using Sawdust — Sustainable Technology for Waste Reduction." *Journal of Cleaner Production* 234 (October): 225–32. <https://doi.org/10.1016/j.jclepro.2019.06.150>.
- Cohen, Marc M., Michael T Flynn, and Renee L. Matossian. 2012. "Water Walls Architecture: Massively Redundant and Highly Reliable Life Support for Long Duration Exploration Missions." In *Global Space Exploration Conference*, 1–14. <http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.397.4625>.
- Derme, Tiziano, Daniela Mitterberger, and Umberto Di Tanna. 2016. "Growth Based Fabrication Techniques for Bacterial Cellulose: Three-Dimensional Grown Membranes and Scaffolding Design for Biological Polymers." *ACADIA : Posthuman Frontiers: Data, Designers And Cognitive Machines*. Ann Arbor, Michigan, USA.
- Flynn, Emma. 2016. "(Experimenting with) Living Architecture: A Practice Perspective." *arq: Architectural Research Quarterly* 20, no. 1: 20-28.

- Flynn, Michael T., Marc Cohen, Renée L. Matossian, Sherwin Gormly, Rocco Mancinelli, Jack Miller, Jurek Parodi, and Elyssee Grossi. 2018. "Water Walls Architecture: Massively Redundant and Highly Reliable Life Support for Long Duration Exploration Missions." *Conference: Global Space Exploration Conference 2018*. Washington, DC.
- Ghazvianian, Ali, Paniz Farrokhsiar, Fabricio Vieira, John Pecchia, and Benay Gursoy. 2019. "Mycelium-Based Bio-Composites for Architecture: Assessing the Effects of Cultivation Factors on Compressive Strength." In *Proceedings of eCAADe*: 505-514.
- Girometta, Carolina, Anna Maria Picco, Rebecca Michela Baiguera, Daniele Dondi, Stefano Babbini, Marco Cartabia, Mirko Pellegrini, and Elena Savino. 2019. "Physico-mechanical and Thermodynamic Properties of Mycelium-based Biocomposites: A Review." *Sustainability* 11, no. 1: 281. doi:10.3390/su11010281
- Gruber, Petra, and Barbara Imhof. 2017. "Patterns of Growth-Biomimetics and Architectural Design." *Buildings* 7: 32. <https://doi.org/10.3390/buildings7020032>.
- Haneef, Muhammad, Luca Ceseracciu, Claudio Canale, Ilker S. Bayer, Jose A. Heredia-Guerrero, and Athanassia Athanassiou. 2017. "Advanced Materials from Fungal Mycelium: Fabrication and Tuning of Physical Properties." *Scientific Reports* 7 (1): 1-11. <https://doi.org/10.1038/srep41292>.
- Hebel, Dirk E., and Felix Heisel. 2017. *Cultivated Building Materials: Industrialized Natural Resources for Architecture and Construction*. Basel: Birkhäuser.
- Islam, M. R., G. Tudryn, R. Bucinell, L. Schadler, and R. C. Picu. 2017. "Morphology and Mechanics of Fungal Mycelium." *Scientific Reports* 7 (1): 1–12. <https://doi.org/10.1038/s41598-017-13295-2>.
- Jones, Mitchell, Tien Huynh, Chaitali Dekiwadia, Fugen Daver, and Sabu John. 2017. "Mycelium Composites: A Review of Engineering Characteristics and Growth Kinetics." *Journal of Bionanoscience* 11, no. 4: 241-257.
- Karana, Elvin, Davine Blauwhoff, Erik-Jan Hultink, and Serena Camere. 2018. "When the Material Grows: A Case Study on Designing (with) Mycelium-based Materials." *International Journal of Design* 12, no. 2: 119-136.
- Lu, Yue, Alex A. Aimetti, Robert Langer, and Zhen Gu. 2016. "Bioresponsive Materials." *Nature Reviews Materials* 2, no. 1: 1-17.
- Mogas-Soldevila, Laia, Jorge Duro-Royo, Daniel Lizardo, Markus Kayser, William Patrick, Sunanda Sharma, Steven Keating, John Klein, Chikara Inamura, and Neri Oxman. 2015. "Designing the Ocean Pavilion: Biomaterial Templating of Structural, Manufacturing, and Environmental Performance." In *Proceedings of IASS Annual Symposia*, vol. 2015, no. 16, pp. 1-13. International Association for Shell and Spatial Structures (IASS).
- Park, Daekwon, and Martin Bechthold. 2013. "Designing Biologically-inspired Smart Building Systems: Processes and Guidelines." *International Journal of Architectural Computing* 11, no. 4: 437-463.
- Stamets, Paul. *Mycelium Running: How Mushrooms Can Help Save the World*. 2005. New York: Ten Speed Press.
- Sun, Wenjing, Mehdi Tajvidi, Christopher G. Hunt, Gavin McIntyre, and Douglas J. Gardner. 2019. "Fully Bio-Based Hybrid Composites Made of Wood, Fungal Mycelium and Cellulose Nanofibrils." *Scientific Reports* 9, no. 1: 3766. <https://doi.org/10.1038/s41598-019-40442-8>
- Vincent, Julian FV. 2012. *Structural Biomaterials*. Princeton: Princeton University Press.
- Wösten, Han AB. 2019. "Filamentous Fungi for the Production of Enzymes, Chemicals and Materials." *Current Opinion in Biotechnology* 59: 65-70.
- Yang, Zhaohui, Feng Zhang, Benjamin Still, Maria White, and Philippe Amstislavski. 2017. "Physical and Mechanical Properties of Fungal Mycelium-based Biofoam." *Journal of Materials in Civil Engineering* 29, no. 7: 04017030. DOI: 10.1061/(ASCE)MT.1943-5533.0001866
- Zhang, Jianfeng, Peipei He, Yichen Lin, Haixia Song, Hao Dong, Xuejun Zhu, and Jiejing Zhang. 2019. "The Cushion Performance of Mycelium-Cornstraw Biofoams." *Journal of Biobased Materials and Bioenergy* 13, no. 4: 484-489.
- Zolotovskiy, Katia. 2017. "Guided Growth: Design and Computation of Biologically Active Materials." PhD diss., Massachusetts Institute of Technology.

INSTITUTIONALIZING CO-PRODUCTION IN THE CONSERVATION AND RENEWAL OF RESIDENTIAL URBAN HERITAGES IN SHANGHAI: The Obstacles and Solutions

Miao Hu
Tongji University

Abstract: In Shanghai, the spatial division inside residential heritages is intricate. Even the smallest top-down renewal projects involve several households' interests. Without an "empowered participatory governance" (Fung and Wright 2003), communities tend to form intense exclusion, refusing government interventions (Tallon 2013). Under such background, in 2017, the author accompanied a co-producing renewal process along with the Shanghai Xuhui district and communities.

This paper reviews the co-production theory, summarizes its advantages of meeting individual demands and utilizing residents' initiative inputs, its nature of breaking current rules and using conflicts tactics, as well as its drawbacks of potential structural and fire-fighting dangers of buildings, as shown in the "Dream Home" TV program.

Then the paper examines the case of No.620 West Jianguo Road, a pilot project of institutionalizing the co-production, aiming at bringing out its merits and eliminating its defects. Two obstacles in this process are elaborated and the reasons for them are analyzed: a) The intricate interests within residents are hard to coordinate only by designers, but the current mechanism doesn't enable the residents to reach a consensus beforehand or integrate them into the design phase. b) The division of ownership and use-right in the history causes unequal duties and rights and mutually restricted power between the residents and the state, resulting in the state's inability to occupy or repair its property as well as the reluctance to support the residents' initiative repair.

Afterward, the paper proposes corresponding solutions based on relevant practical references, focusing on optimizing and deepening the mechanism of state-community engagement in the residential renewal, and adjusting the rights, responsibilities, and benefits of the owners and users.

To sum up, this research suggests that a "public-sector led" co-production may be still possible, with a changed power balance and certain modification to the current rules, and could achieve unexpected results when the state has difficulty in delivering services; whereas the shift of planners' roles indicates that empowerment may be gradually taking place.

Keywords: Co-production, historic conservation, residential urban heritage, urban renewal, Shanghai

INTRODUCTION

Shanghai has a wealth of residential historic urban heritage resources, with a large area and a wide range, including numerous high-quality residential buildings, apartments, and garden houses. However, long-term, over-loaded, and extensive use has accelerated the aging of the buildings, causing their living environment to deteriorate continuously, making their protection and renewal often unsatisfactory.

For a long time, relocating the residents as a whole and adjusting the buildings' function were among the main approaches to renewing historic blocks, which, however, left two drawbacks: a) The buildings with lower protection-degree and less-prominent historic value, or those, whose stock is still large, are often demolished and replaced with high-rise buildings by developers in the desire for the maximum economic benefit. b) The removal of many indigenous residents in a short time

causes irreparable damage to the communities' social networks, as well as an abnormal growth of social structure and urban fabric in the region.

The ever-increasing costs and the difficulty of resettlement drove Shanghai to seek a new method of redevelopment and resulted in the city's clear statement in 2016 that 7.3 million square meters of traditional dwellings in the central city should be conserved. Since the gradual decrease of the excessive residents' amount still takes a considerably long time, the government undertook the improvement of the interior living condition of historic buildings step by step, expecting that residents' private investment can be incentivized through public investments like the addition of a private kitchen and bathroom.

However, this "indoor spatial renewal" faced no small challenge. The interior space segmentation of

Shanghai's residential heritage is quite complex, and even the tiniest top-down renewal projects involve the interests of several households. Without "empowered participatory governance" (Fung and Wright 2003), communities tend to form strong oppositions and resist the government's intervention (Tallon 2013).

A typical case is Jukui New Village (figure 1), a community with three-story historic buildings built in the planned economy era. It lacks kitchen and bathroom facilities, but has a large number of households and informal construction: 262 of the 309 households in the community constructed 432 illegal structures; the original 2 to 3 meter-wide alleys were gradually eroded by the residents' self-constructed "small compartments"; the spontaneous structures were built up to six floors tall, supported by a mere two thin steel pipes. All of these caused damage to the architecture and brought about security risks. In 2016, the government began to renovate the buildings and tried to add private kitchens and bathrooms for the residents as much as possible. The results of the repair were acknowledged and praised by the residents and the public at first, however, after a few months, nearly 70% of the residents petitioned and complained. The reason is that, after comparing with each other, the residents found that due to various considerations, such as construction quality and the interior spatial layout, the space added by the designers to each household was not completely equal, causing strong dissatisfaction among the residents. At that time, the residents had already signed agreements with the government and moved back in, and the design could not be changed anymore. Residents believed that, since the repair work was led by the government, the "loss" caused by the uneven distribution of interests should be compensated by the government as well. In the end, the government was overwhelmed with responsibilities, and the preservation and renovation became stuck in a deadlocked-situation.

Given this context, the Shanghai Xuhui District Housing Management Bureau proposed to explore a method of "co-producing residential renewal", expecting to resolve conflicts of interests and achieve satisfactory renewal results, by encouraging residents' initiative action and acknowledging their contributions and efforts in the renewal.

1. LITERATURE REVIEW

1.1. INTERNATIONAL THEORY AND PRACTICE OF CO-PRODUCTION

Co-production is a term of state-society engagement around urban development issues, which is often related to the cases (especially in the global South), in which the poor communities rely on their capability to improve their living conditions. Its background is the obvious progressive ineffectiveness of formal democracy in achieving the democratic political ideal (Fung and Wright 2003). Therefore, an "empowered participatory governance" with an institutional design is needed, which counts on the input and ability of ordinary people, and ties action to debates (Fung and Wright 2003). This also indicates the state-society engagement has entered a "post-collaborative" phase, with the focus shifting to the difficulties met in the process, as well as the context and conditions in which participation takes place (Brownill and Parker 2010).

The term "co-production" originated from the political economist Elinor Ostrom in 1996 and was defined as a process where the inputs of individuals not in the same group are transformed into goods and services (Ostrom 1996). It emphasizes the complementary advantages of the government (in resources, technical experts, and trunk service) and communities (in local information, time, skills, and feeder service), which generates a synergistic effect leading to better results. Compared with the former concepts of



Figure 1: Jukui New Village before (left) and after (right) renovation. (<http://sh.sina.com.cn/news/m/2020-07-23/detail-iihvpwx6958937-p3.shtml>)

"collaborative" and "communicative" planning, these three concepts are not approaches to radical social changes, but about state-society cooperation in improving the citizens' living conditions (Watson 2014). However, the co-producing method often inevitably goes beyond, or even counter to the existing governance rules, and underscores the importance of communities' gradual empowerment (Watson 2014), while the other two concepts are always carried out within the existing rules, regarding power only in deliberative planning process and assuming its destructive effect can be overcome through debate (Huxley 2000).

Co-production has different variants interpreted by scholars. Bovaird (2007) argues co-producing means a redistribution of power, which is highly political and could result in undesirable social effects; it is, therefore, necessary to "reserve power of state regulation". Whereas the social movement initiated co-production affords power against that of the state, with community organizations and NGOs playing an important role, its practice could be a combination of both conflict (protests for example) and cooperation (Bradlow 2013).

Traditional planning tools like survey and mapping, which used to be held within the government, are seen by co-production as a combination of power and knowledge and used by marginalized groups to claim space and speak back to the state (Watson 2014). In some cases, the whole process from the survey, visioning, and construction to management has been undertaken by the community, is referred to as a self-mapping and approved by the state; the role of the state here lies mainly in granting land and tenure, and providing larger infrastructure (Archer 2012). Correspondingly, architects and urban planners also shift from "know-all" professional experts to community supporters, in the recognition that "only the poor know how to live in poverty." Co-production argues that planners should "offer right guidance rather than control the whole progress", should "ask right questions" rather than provide answers, should play a "teaching role" to train communities towards sustainable development without the planners' intervention (Archer et al. 2012).

What is noticeable here is that power and conflicts within the community need paying attention to (Robins et al. 2008). As well, the form and effectiveness of co-production may differ in alternate contexts. Although co-production is a more radical method seeking the "fundamental change of the power balance," it could still be "public-sector led" (Albrechts 2013).

1.2. THEORY AND PRACTICE OF CO-PRODUCTION IN CHINA

In China, with the economic system reform deepening, the community has gradually taken on more social tasks

and became the focus of urban governance. Its essence lies in advocating the dispersion of power and adopting a city development method with local suitability and uniqueness (Wang 2006).

In recent years, with regard to the "co-producing" preservation and renewal of residential urban heritages, Chinese scholars have proposed different institutional construction strategies, such as the establishment of a communication and dialogue mechanism like hearings and workshops (Zhang 2004), the appointment of community planners (Ye 2006), the introduction of non-profit organizations to mediate the contradictions in urban renewal (Hong L. 2013), and the empowerment of neighborhood committees to manage communities' public welfare affairs on their own (Ouyang 2015). Strategies of adjusting the property rights' relationship were put forward as well, such as the privatization of property rights (Xiao 2004), the socialization of property rights (Wang et al. 2004), or the public-private-shared ownership of property rights (Guo 2007), etc., aiming at encouraging residents' investment and dedication in housing protection and repair, through the establishment of a differentiated property rights system. However, scholars generally believe that the current depth and breadth of residents' engagement is far from enough, and its participant, organizational capacity, and impact on planning is still weak when lacking professional support (Hong and Zhao 2013; Zhao and Li 2015; Ouyang and Ye 2015).

1.3. "DREAM HOME" PROGRAM AS AN ENLIGHTENMENT

A TV Program from Shanghai called "Dream Home" took the lead in introducing a new situation of "co-producing" residential renewal methods. In this program, the households living in historic buildings (often owned by the state) ask the TV station for renovation help and the TV group invites architects to create interior designs. The results show that such renovation focused on residents' individual demands, motivates the initiative of residents' repairs, has high repair efficiency, generates satisfactory results, and fosters the community's acquisition of knowledge by showing and learning by doing (McFarlane 2011), and thus has received a lot of praise and attention from the academy. On the other hand, this method also received criticism from the government departments (i.e. the district real estate corporation and the housing management department). Due to the lack of institutionalized rules and residents' and designers' inadequate knowledge of housing structure and heritage protection, renovations often dig the foundation or remove load-bearing walls to improve the indoor spatial layout, resulting in damage to the historic buildings' integrity and safety, which also runs

counter to the goal of historic preservation and the improvement of residents' living conditions.

However, because of the potential it has, the housing management department of Xuhui District of Shanghai still decided to institutionalize this renewal method, with the residents' self-conducted repair standardized and guided. No. 620 West Jianguo Road was chosen as a pilot case.

2. A CASE OF INSTITUTIONALIZING CO-PRODUCING RESIDENTIAL RENEWAL: NO.620 WEST JIANGUO ROAD

No. 620 West Jianguo Road (figure 2) is a three-story garden house built in 1924, adjacent to the Polish consulate, and acknowledged as an outstanding historical building. It covers an area of about 130 m², with a brick and wood structure in the German *Jugendstil*. The building was once used as a kindergarten and later assigned to the kindergarten staff as a welfare house, with a modified layout. After a long period of development, there are currently fourteen households in this building, with a total area of less than 400 m². The residential density far exceeds the initial design parameters.

Each floor can be divided into two parts: private rooms, where households live, and public spaces, where two small washrooms and a kitchen are located and shared by the residents living on the same floor. The public space is divided intricately and occupied by different households following an unwritten rule. The smallest household living area is only 5.8 m², located on the ground floor, and the overall living condition is sub-standard.

In March 2017, the Xuhui District Government researched the conservation and repair plan for the

building, aiming to improve the internal living conditions, according to the residents' demands and with their own engagement. A design team from Tongji University was entrusted with coordination, in which the author is also a key member. During the community sessions, residents generally expressed their hopes for individual private kitchens and washrooms, and the designers started to develop a plan based on this request. However, the institutionalizing process of co-production revealed that two obstacles still need to be tackled.

2.1. FIRST OBSTACLE: INTERNAL INTERESTS' CONFLICTS AND DEFECTIVE PARTICIPANT MECHANISM

The first practical difficulty is the complex relationship of interests among the residents. Under the current public participant procedure, residents are rarely integrated into the renewal design, and it is therefore hard to achieve a consensus.

In the first version of the design, some units of private spaces were changed, and some indoor living spaces were moved to make room for separate kitchens and bathrooms, while the original public space on each floor was retained. However, this design was opposed by the residents. The residents believed that the private living space of the building should be at their own disposal, whereas the government's intervention should be restricted only to the public part and should not interfere in their private rooms.

In the second version of the design (figure 3), the public space on each floor was divided into independent kitchens and bathrooms as much as possible, according to the residents' requirements, and was integrated into the private rooms of the residents, so that each household could enjoy individual kitchens



Figure 2: Current Situation of No. 620 West Jianguo Road.
(Author 2017)

and bathrooms while keeping the original living area from being decreased. However, the inequality of the increased kitchen and bathroom areas between each household is still inevitable. For example, the No. 5 and No. 2 households on the ground floor have the most obvious contrast: the original living area of the No. 2 household is 5.8 m², and the design plan increases the kitchen, bathroom and storage room area by 9.42 m², which is about 162.4% of the original living area; The original living area of the No. 5 household is 24.9 m², and the design plan increases the kitchen and bathroom area by 8.51 m², which is about 34.2% of the original living area. The increased kitchen and bathroom areas have a large gap in proportion, which incited opposition from the No. 5 household. They believed that, since their original living area was 3.29 times larger than that of the No. 2, in order to be fair the kitchen and bathroom allocated to them should also be much larger than that of the No. 2 household. A similar situation also involves the No. 3 household on the ground floor who did not agree to give part of their original living area to the No. 6 household as a kitchen and bathroom, although their spatial loss was compensated accordingly in the design. The extensive work of coordinating such interests tired out the designers and slowed down the renewal progress.

An ideal method would be for the residents to reach a consensus on the distribution of benefits at the beginning and get directly involved in the design procedures, and the designer designing, according to the residents' instruction. Currently, an appropriate mechanism is lacking. In the present state-owned buildings' renewal project, there are two main links involving the residents' participation (figure 4):

- a) Consultation and entrustment: The renewal plan should seek the opinion of all the tenants or owners of the buildings, and obtain more than two-thirds of the tenants or owners' approval, before a construction team can be entrusted and the implementation begun.
- b) Signing the agreement: For the design and the comprehensive implementation plan of the renewal projects, the property owner (in most cases the housing management department) should sign an agreement with all the residents.

However, there is no institutionalized residents' cooperation introduced during the key phase of "planning and design" that involves "what to renew", and the phase of "implementation" that involves "how to renew and who leads the renewal". Participation is relatively low-level and is concentrated in the later stage of the renewal project, resulting in the asymmetry of

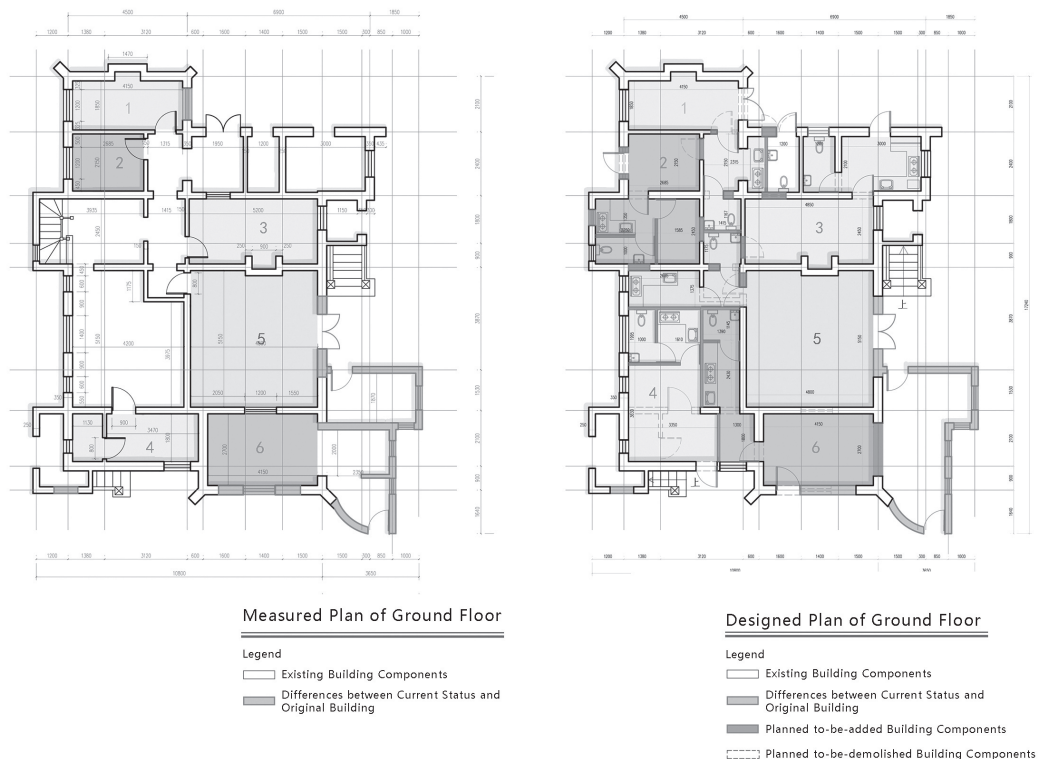


Figure 3: Current situation (left) and the renewal plan (right) of No.620 West Jianguo Road. (Author 2017)

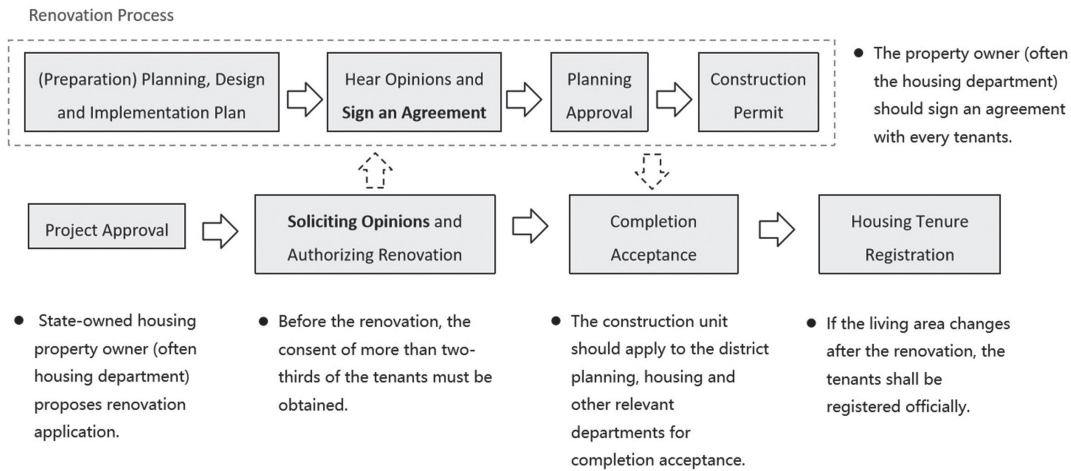


Figure 4: Current renewal process of state-held houses in Shanghai. (Author 2017)

information and the lack of communication between the design team and the residents. As seen in the “Jukui New Village”, when the residents collectively poured into the phase of “signing agreements” at the same time and were asked to accept the renewal design, long-standing conflicts would inevitably break out.

2.2. SECOND OBSTACLE: UNEQUAL DUTIES AND MUTUALLY RESTRICTED POWER BETWEEN THE RESIDENTS AND THE STATE

The second difficulty encountered by the renewal project was that when submitted for official review, the design proposal, which was finally negotiated with the residents, was rejected by the government. The reason lies in the special system of property rights (figure 5). Shanghai’s residential historic buildings are mainly state-owned, whose property rights are divided into two parts: the ownership belongs to the government, and the right to use the house belongs to the residents, whose names with corresponding living areas are recorded in the official documents. The use-right was once given to citizens as welfare during the planned economy era, and with the promulgation of a series of legal norms in the last decades, the use-right of the state-owned houses was gradually recognized as a formal part of the property rights. In the current public housing lease relationship, the house is practically controlled by the use-right holders. For example, the residents can enjoy the right to lease the house at a very low rent for unlimited time. They can also enjoy the full profit (usually dozens of times the rent paid to the government), if the house is sublet. But when there is an (even very tiny) problem with the house, and it needs

repairing, the residents will always turn to the property owner (the government) for help.

Thus, a paradox is apparent. On the one hand, the government undertakes a large number of repairing obligations, but is unable to exercise its rights of using or disposing of the state-owned houses and cannot obtain the benefits brought by the renewal of the houses. Without the permission of the use-right holder, the government is not even able to repair or renew the internal structure or space of the house. For example, the previous “water supply” improvement project was often resisted by the residents because it might bring tiny changes to their living space. The government invested a lot but gained no return and has thus, in the end, only limited enthusiasm for such initiative. On the other hand, unless the government department agrees, the residents, as well, cannot carry out house repairs or renewals arbitrarily. The responsibilities of the government and residents are not equivalent, and their power is mutually restricted. As a result, in the past, residents’ inappropriate and careless use of the houses has been the norm. Some buildings have even been treated with an attitude of “let it decay” by the residents to obtain the compensation for demolition.

3. SOLUTION FOR THE INSTITUTIONALIZATION OF CO-PRODUCING RESIDENTIAL RENEWAL

Given the two obstacles above, this paper refers to relevant practical cases and proposes solutions, focusing on improving and deepening the mechanism of state-community engagement in the residential renewal, and adjusting the rights, responsibilities, and benefits of the owners and users.

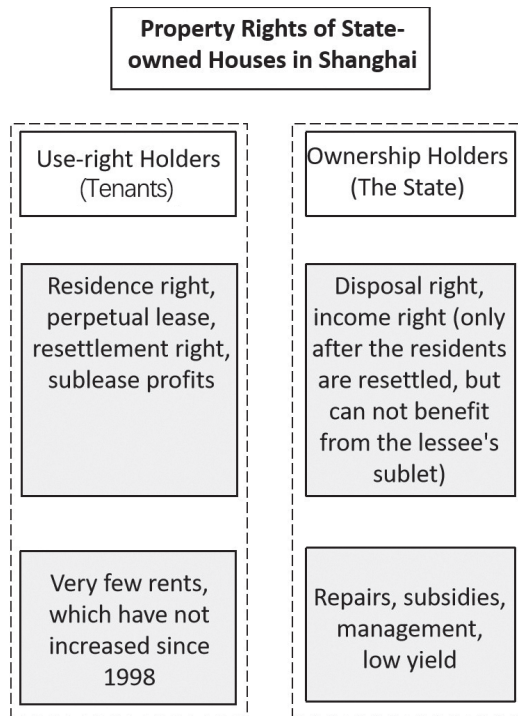


Figure 5: Analysis of the property of state-held houses in Shanghai. (Author 2017)

3.1. AUTONOMOUS NEGOTIATING MECHANISM AND ACCOMPANYING PLANNING PROCEDURES

Given the residents' intricate spatial interests, it is first necessary to establish an appropriate internal negotiating mechanism for subsequent successful design work. A suggestion here is to rely on the resident committee's strong social capital, and let the committee conduct the coordination autonomously, with the help of external professional social organizations.

A valuable reference is the "Family Indoor Renovation Project" carried out by the Bund community in Huangpu District in 2016, in cooperation with the non-profit organization Habitat for Humanity. The project was technically supported by professional volunteers convened by the social organization, and financially supported with funds donated by enterprises. The community committee first recorded the demands and backgrounds of the voluntarily participant families and organized the hearings to select the suitable households. Then the qualified households reached an agreement with the social organization before the renewal started on issues such as neighborhood mediation, legitimate renovation, and no-sublet. In this way, the coordination could be completed at the beginning of the project, thus facilitating the implementation afterward.

As well, a repair-items-list could be formulated along with the establishment of the renewal project. Residents living in the same building unit can act as a whole and select what needs repairing. After a consensus is reached, they should ask for neighbors' opinions and propose the renewal application to the government. Then, the relevant departments offer investment and qualified construction teams to help with implementation. During the design phase, the designers and residents can form a temporary co-working team. Meanwhile, certain financial power and authority should be given to the community committee, so that they can integrate and utilize the resources and manage community affairs independently.

Successful experience can be drawn from the mechanism of elevator construction in old communities in Shanghai. It is organized autonomously by the agreement of 90% of the residents in the same building and two-thirds of the residents in the community. After completion, the residents can receive a subsidy of up to 40% of the cost, to not exceed 240,000 CNY. The community committee and relevant departments are supposed to assist in the application and approval procedures. With a strong initiative, willingness to act and a well-developed policy system, in the first half-year of 2019, 311 old buildings were equipped with elevators effectively.

To acknowledge and include the residents' efforts in the design and obtain a satisfactory renewal result, the establishment of the community-planner-system should be accelerated, the design-workshops and regular hearings should be introduced, and the residents should be accompanied by professionals and engage themselves in the preservation and renewal of residential urban heritage.

The Chengxingli renewal project (figure 6) in Huangpu district from 2018 brought forward a "one design for one household" strategy, in which the designers communicated with each household at the very beginning of the project, recorded their demands and the way they use or change the rooms, and modified the design several times to suit the residents' original living conditions. The design is detailed into the types of window opening and the location of furniture. In fact, a "customized service list" was formulated in the renewal, where residents could customize the area of the added kitchens and washrooms, the appearance of the furniture, as well as the location of the electrical sockets.

3.2. ADJUSTING BENEFITS-RELATIONS AND CLARIFYING POWER AND DUTIES BETWEEN THE RESIDENTS AND THE GOVERNMENTS

As to adjusting the property relationship, institutional economics believes that property rights include all rights to resource utilization and compose the "rights bunch",



Figure 6: Kitchens in Chengxingli can be customized according to the residents' needs (middle). The renovation is based on residents' demands, in line with the user's habits (right). (Author 2019)

and thus possessing the whole property rights is only an ideal. For residential urban heritages, which are usually owned by the state, since the use-right holders are allowed legally to sublease the houses for profit, the property owner could further transfer certain rights to use-right holders, including the self-conducted repair and renewal, and encourage such actions. Meanwhile, governments should adjust the current rent rules to set differentiated rents for the sublet and self-occupied houses respectively, which can also be seen as taking back part of the right of subletting and profiting.

A successful reference here is the "Les Pentes de la Croix-Rousse" in Lyon, France. It encourages residents of historic neighborhoods to renovate their own houses with differentiated subsidies, which are classified into two kinds, based on whether the house is for self-occupation or sublet. For sublet houses, if the owner is to rent at a market price, then they will receive no more than 25 % of the renovation cost; if the owner agrees to rent at the price of social houses in nine years, they will receive no more than 55 % of the renovation cost; if the owner rents at the lowest housing price, they will receive up to 85 % of the renovation cost. For self-occupied houses, the government will offer subsidies according to their family incomes. Meanwhile, the city assists the residents in the repair management through an NGO. If the tenant of the social houses were not able to pay rents in time, the NGO would pay for them in advance, so that the income of the house-owners would not be affected.

For the balancing of the residents' and government's responsibilities and rights, a *Guideline toward Preservation and Utilization* can be formulated to clarify what kinds of autonomous, self-repair actions by residents are approved. Currently, Tongji University has been entrusted to formulate the *Guideline for Preservation and Utilization of Yide Apartment by Jing'an District Government* and the author is among the key team members. The guideline stipulates the key

protected architectural parts, the permitted items of self-conducted repair and their requirements, the repairs that should be reported to the government for review and their corresponding procedures. It aims to improve the working efficiency of historic preservation, regulate residents' daily maintenance activity, and avoid possible damages to the urban heritage.

CONCLUSION

Co-production can meet residents' demand, utilize individual inputs effectively and achieve unexpected results when the state is unwilling or unable to deliver services (Watson 2014). Meanwhile, co-production often goes beyond or counter to the existing rules and use conflict tactics. However, co-production may still be "public-sector led" in certain contexts, although the power balance has fundamentally changed (Albrechts 2013). Therefore, it is possible to highlight the advantages of residents' own initiative and eliminate potential institutional costs and social risks, by institutionalizing co-production actively and adjusting current rules.

The case of No. 620 West Jianguo Road indicates the conflicting interests within the communities can become an endogenous influence against a successful co-production, and the power-relations (property included) between the residents and the state can be a restraining factor. A good co-production needs an effective internal negotiating mechanism for the community, the willingness, ability, and recognition of the residents' self-mapping or design, as well as empowerment from the state. For this, current rules may have to offer more potential openings. Meanwhile, the state ought to formulate repair-guidelines to clarify and restrict residents' actions and adjust the relation of benefits in the state-society engagement and restore the balance of power.

Noticeable is the work of planners shifting from expert driven reviews to "action-research approach"

(Huchzermeyer and Misselwitz 2016), as shown in Jianguo Road 620. "Mapping and planning" as a combination of power and knowledge (Watson 2014) also shifts from being held by the state to being shared with the community, even partly conducted by residents independently, which suggests the empowerment may be gradually taking place.

It is worth discussing how to define or redefine "community design," "participatory design," and "community architects" in the specific context, namely use-right without property rights.

In Shanghai, the origin of community design is similar to that of the US in the 1960s, when it was recognized that professional design techniques alone are inadequate in resolving social problems (Sanoff 2006), and that its main purpose, likewise, offering design and planning services for residents (often economically disadvantaged groups) to involve them in shaping and managing their environment (Sanoff 2006). More non-profit community organizations are likely to subsequently emerge in Shanghai too. However, while the capacity of community design centers in the US address environmental risks and poverty is diminishing, and the groups with economic clout use participatory techniques to resist changes, enhance their power and secure their quality-of-life (Sanoff 2006), in Shanghai, such contradiction lies not between the poor and affluent groups, but more in the intricate spatial interests among

residents and in the power-benefits relations between the state and communities. Hence, the establishment of a negotiating mechanism and the adjustment of the property system are two core dimensions. For a successful interior spatial renewal of historic houses, residents must be empowered with authority and responsibility to take proactive actions instead of resistant ones (Sanoff 2006), with residents seen as the center in both planning and implementation, which resembles community building in the US, to some extent.

Similarly, in Shanghai's context, participation should focus more on how to achieve an accurate balance among residents' spatial interests via in-depth co-work and further realize their full range of needs and desires in the design (Milgrom 1998), rather than serving as a tool for "defending exclusionary, conservative principles" or for "promoting social justice and ecological vision" (Sanoff 2006). Consultation is inadequate alone since it only represents the lowest common solutions, which the majority can tolerate (Milgrom 1998).

In co-productive process, "community architects" should help individuals be included in the decision-making process (Milgrom 1998) and assume a more proactive role than their traditional counterparts, who thought they knew best how people should live (Sanoff 2006). They should also serve as representatives for the residents and advocate for their benefits before the state.

REFERENCES

- Albrechts, L. 2013. "Reframing Strategic Spatial Planning by Using a Coproduction Perspective." *Planning Theory* 12, no. 1: 46–63.
- Archer, D. 2012. "Finance as the Key to Unlocking Community Potential: Savings, Funds, and the ACCA Programme." *Environment and Urbanization* 24, no. 2: 423–440.
- Archer, D., C. Luansang, and S. Boonmahathanakorn. 2012. "Facilitating Community Mapping and Planning for Citywide Upgrading: The Role of Community Architects." *Environment and Urbanization* 24, no. 1: 115–129.
- Bovaird, T. 2007. "Beyond Engagement and Participation: User and Community Co-Production of Public Services." *Public Administration Review* 67, no. 5: 846–860.
- Bradlow, B. 2013. "Quiet conflict: Social movements, Institutional change, and Upgrading Informal Settlements in South Africa." Master's thesis, Massachusetts Institute of Technology.
- Brownill, S., and G. Parker. 2010. "Why Bother with Good Works? The Relevance of Public Participation(s)." In *Planning in A Post-Collaborative Era*. *Planning Practice and Research* 25, no. 3: 275–282.
- Fung, A. and E. Wright. 2003. *Deepening Democracy: Institutional Innovations in Empowered Participatory Governance*. London: Verso.
- Guo, X. 2007. "Is Privatizing House Property Right a Catholicon to Preserve Inner City?" *City Planning Review* 31, no 1: 9-15.
- Hong, L. and Q. Zhao. 2013. "Towards Community Development in Urban Renewal Experience of America and Japan and Implications to China." *Urban Development Studies* 20, no.3: 21-24+28.
- Huchzermeyer, M. and P. Misselwitz. 2016. "Coproducing Inclusive Cities? Addressing Knowledge Gaps and Conflicting Rationalities Between Self-Provisioned Housing and State-Led Housing Programmes." *Current Opinion in Environmental Sustainability* 20: 73–79.
- Huxley, M. 2000. "The Limits to Communicative Planning." *Journal of Planning Education and Research* 19, no. 4: 369–377.
- McFarlane, C. 2011. *Learning the City: Knowledge and Translocal Assemblage*. Chichester: Wiley-Blackwell.
- Milgrom, R. 1998. "Sustaining Diversity Participatory Design and Urban Space." *Planners Network*, last modified May 6, 1998. <https://www.plannersnetwork.org/1998/05/sustaining-diversity-participatory-design-and-urban-space/>

Institutionalizing Co-production in the Conversation and Renewal of Residential Urban Heritage in Shanghai

- Ostrom, E. 1996. "Crossing the Great Divide: Coproduction, Synergy, and Development." *World Development* 24, no. 6: 1073–1087.
- Ouyang, H. and Q. Ye. 2015. "Resilience of the Community Regeneration Mechanism: Inspirations from UK Models." *Urban Development Studies* 22, no. 12: 63-69.
- Robins, S., A. Cornwall, and B. von Lieres. 2008. "Rethinking "Citizenship" In the Post-Colony." *Third World Quarterly* 29, no. 6: 1069–1086.
- Sanoff, H. 2006. "Origins of Community Design." Planners Network, last modified January 2, 2006. <https://www.plannersnetwork.org/2006/01/origins-of-community-design/>
- Tallon, A. 2013. *Urban Regeneration in the UK*. London; New York: Routledge.
- Wang, D. 2006. "Establishment of Public Participation System of Urban Planning with Community as the Core." *Planners* 13, no. 5: 68-72.
- Wang, L. and Y. Shao. 2015. "Historical Residence Renewal from the Perspective of Existing Built Environment Renewal: Discussion on Gradual Living Condition Improvement Based on Negotiation." *Shanghai Urban Planning Review* 19, no. 4: 101-107.
- Wang, X. and X. Chen. 2004. "A Study of Conservation and Development of Buildings with Historical Significance from the Point of Institutional Economics." *Journal of Tongji University Social Science Section* 15, no. 5: 97-102.
- Watson, V. 2014. "Co-Production and Collaboration in Planning: The Difference." *Planning, Theory & Practice* 15, no.1: 62-76
- Xiao, J. 2004. "On the Market-Oriented Operation of the Protection and Utilization of Historical Buildings." *Shanghai Real Estate* 8, no.2: 31-31.
- YE, W. 2006. "Inspiration Drawn from Self: Help Construction of Community in Britain For Renewal of Community in China." *Planners* 13, no. 3: 61-63.
- Zhang, G. 2004. "Towards Three-Way Partnership in Urban Regeneration: The Western Experience and Implication to Chinese Cities." *Urban Development Studies* 11, no. 4: 26-32.
- Zhao, M. 2007. *Investigation of The Social Problems in The Process of Revitalizing Historic Quarters*. Shanghai: Tongji University.
- Zhao, Q. and Z. Li. 2015. "Planning Strategies for The Renewal of Old Urban Residential Areas in the Transition Period." *New Architecture* 32, no. 4: 125-127.
- Zhou, X. and Y. Cheng. 2019. "From Morphology to Institution: Discussion on the Reorientation of Shanghai Historic Lane Neighborhood's Urban Functions Through the Transformation of Property Ownership and Land Usage." *Urban Development Studies* 26, no. 5: 63-72

THE FEASIBILITY OF NATURAL VENTILATION IN CHICAGO'S TALL OFFICE BUILDINGS USING DOUBLE-SKIN FAÇADES

Yohan Kim
Illinois Institute of Technology

Abstract: Thirty-one tall buildings (i.e., buildings of or taller than 200 m) have been erected to date in Chicago; 51% accounting for office function, according to the Council on Tall Buildings and Urban Habitat (CTBUH). Their energy-efficiency and healthy environment have become important concerns, given the current environmental challenges and health considerations. Many strategies in improving the properties of windows and building systems have been adopted to save energy and improve the working environment in tall office buildings in Chicago. However, only a few passive design techniques for natural ventilation have been employed. Double-skin façade (DSF) systems can provide an opportunity to apply natural ventilation strategies to tall office buildings, as they can mitigate the high wind speed and pressure through the additional skin and regulate the vertical stack flows through the segmentation. This study will investigate the feasibility of natural ventilation in Chicago's tall office buildings using DSFs. Computational fluid dynamics (CFD) simulations will be conducted to assess the performance of parametric DSF configurations, including opening size and location, cavity depth, and cavity segmentation based on indoor air velocity, indoor operative temperature, and air change rate calculated under specific climatic conditions in the simulations. These results, as related to thermal comfort and indoor airflow behavior, are important criteria for the ventilation requirements established in the ASHRAE standard. Wind tunnel tests will be conducted to validate the CFD simulation results. The DSF configuration is a key determinant of the distributions of air velocity and indoor temperature on each floor, and the proportion of driving forces between wind and stack effects. In order to assess the feasibility of natural ventilation in tall office buildings, which rely highly on mechanical ventilation, the maximum number of natural ventilation hours throughout the year in Chicago will be predicted based on the analysis of the simulation results and the weather data. The proper DSF configurations with quantified natural ventilation will lead to a better understanding of how DSFs should be designed for tall office buildings and provide a performance-based design guideline for the early design stage in which iterative and rapid design decisions are made.

Keywords: Double-skin façade, natural ventilation, tall office building, CFD simulation

1. INTRODUCTION

1.1. ENVIRONMENTAL CHALLENGES AND HEALTH CONSIDERATIONS

The City of Chicago is the home to tall buildings, the birthplace of the skyscraper, and one of the first places in which the innovative design and engineering of tall buildings emerged. According to the Council on Tall Buildings and Urban Habitat (CTBUH), there are thirty-one tall buildings (i.e., buildings of, or taller than, 200 m) to date in Chicago. More than half of them are dedicated to office functions. Four more tall buildings are expected to be completed in the next three years (CTBUH 2019). Increasing urban population, increasing land prices, green land preservation needs, global competition, and emerging technologies contribute to this trend in cities (Sev and Aslan 2014). Most tall office buildings rely highly on mechanical systems and consume extensive amounts of energy compared to other types of buildings. In climate zone 2, including Chicago, as defined by U.S. Energy Information Administration (EIA), 35% of total energy consumption is

responsible for HVAC systems in commercial buildings by end use (EIA 2002). The total amount of electricity consumed in commercial buildings has consistently increased over the years, due to the use of new types of electronic equipment and existing technologies such as computers, office equipment, and so on (EIA 2012). The use of these electronics can lead to more electricity consumption due to additional cooling loads and ventilation equipment. In addition to energy consumption in tall office buildings, the sealed tall office building, relying on mechanical ventilation, can cause Sick Building Syndrome (SBS), which consists of various nonspecific symptoms. According to some studies, SBS symptoms are correlated with insufficient ventilation. Moreover, insufficient ventilation can cause occupant health problems and the decrease in occupant productivity (Sundell et al. 2011; Fisk et al. 2012). Therefore, the energy-efficiency and healthy environment of tall office buildings have become important concerns, given the current environmental challenges and health considerations.

1.2. CHALLENGES TO FACILITATE NATURAL VENTILATION IN TALL OFFICE BUILDINGS

It is still a challenge to apply natural ventilation to tall office buildings due to the strong winds and the fluctuations that are possibly experienced at upper floors, the possible extreme stack flows, and the deep lease span determined by economic, floor planning, and structural aspects.

Although there are some naturally ventilated tall office buildings, only narrow, operable windows with perforated panels are implemented in most cases, due to the strong winds (based on the case studies in Wood and Salib 2013; Li 2012). Theoretically, if the average wind speed at 10 m is 4.47 m/s (i.e., the windiest months on average in the Chicago area), the average wind speed at 300 m is about 11.58 m/s based on the log wind profile equation. Only a few naturally ventilated tall office buildings with double-skin façades (DSFs), taller than 200 m, have been developed (e.g., Commerzbank Tower in Frankfurt, Germany). Effective natural ventilation requires the buildings to have narrow lease spans, atriums, and solar chimneys that may not be preferred for the design of tall office buildings due to the initial construction costs, the loss of rentable space, structural aspects, etc. Thus, most of the naturally ventilated tall office buildings with DSFs are still shorter than 200 m based on the information collected from available databases (BestFacade, Japan Sustainable Building Database), online sources (ArchDaily), and studies (Lee et al. 2002; Oesterle et al. 2001; Poirazis 2004). The indoor airflow behavior affected by multi-story DSF components in naturally ventilated tall office buildings taller than 200 m has not been fully investigated, as predicting the airflow behavior and quantifying natural ventilation are challenging due to the possible fluctuating wind speed and direction around tall buildings.

The height of tall buildings possibly causes extreme stack flows with respect to the large pressure differentials between the top and the bottom (Wood and Salib 2013) and thus, the unfavorable stack flows can also take place in the extensive cavity of multi-story DSFs. These stack flows in the cavity may cause occupant discomfort when the windows on the inner skin are open. Further, the stack flows may deliver overheated cavity air to the upper floors, which affects the indoor temperature of the adjacent spaces possibly requiring additional cooling loads. According to some studies (e.g., Gratia and Herde 2007; Wong et al. 2008; Larsen et al. 2015), DSFs may cause overheating problems as the façade is highly glazed and the absorbed heat from solar radiation may be retained in the cavity. Only a few studies (e.g., Wong et al. 2008; Nasrollahi and Salehi 2015) considered wind effect as a driving force, which not only improves the airflow in the

cavity, but also removes the heat from it. Therefore, wind effect can be harnessed to facilitate natural ventilation and reduce overheating problems. However, due to the potential magnitudes of driving forces generated by wind and stack effects in tall buildings, the façade design of tall buildings entails more challenges than low rise buildings (Etheridge and Ford 2008). Therefore, the balance between stack and wind effects in the cavity can be a key determinant of effective natural ventilation in tall office buildings with DSFs. The segmented cavity of DSFs should be carefully considered to avoid possible discomfort at upper floors of tall office buildings with respect to overheating and stack flows.

Narrow plan width is one of the typical features of naturally ventilated buildings, including floor-to-ceiling heights of approximately 3 m, good solar control, high thermal capacity, and well-designed adjustable openings (CIBSE 2005). There is no specific standard for the lease span of tall buildings, but some studies suggested the range based on case studies. According to a study by Cho (2007), 80 % of high-rise office buildings have a lease span of 10 to 15 m. The depth of the lease span should be between 10 m and 14 m for office functions due to economic aspects, floor planning, and structural requirements (CTBUH 1995). CIBSE applications Manual A10 suggests wind-driven ventilation strategies with respect to the ratio of floor width (W) and height (H): (1) Single-sided ventilation with single opening ($W \leq 2H$), (2) Single-sided ventilation with double opening ($W \leq 2.5H$), and (3) Cross ventilation ($W \leq 5H$) (CIBSE 2005). However, the proper depth of lease span for effective natural ventilation in tall office buildings with DSFs may not be determined by the requirements and the suggestions mentioned above due to the combined effect of two main driving forces, such as wind and stack effects in the cavity.

2. OBJECTIVES

This study will investigate the feasibility of natural ventilation in Chicago's tall office buildings using DSFs. This study will specifically: (1) quantify the natural ventilation performance of a tall office building with DSFs by conducting computational simulations and wind tunnel tests. Quantifying the performance is important to understand the indoor airflow behavior and the complicated heat transfer that takes place in the cavity and the adjacent indoor spaces, (2) assess the performance of parametric DSF configurations, including opening size and location, cavity depth, segmentation based on indoor operative temperature, indoor air velocity, air change rate, and the number of natural ventilation hours under the specific climatic condition in Chicago, and (3) develop a performance-based DSF design guideline that can be used in the early design

stage. Passive strategies should be discussed earlier in the design process, as they can considerably affect building forms, structures, materials, and systems.

3. METHODOLOGY

The natural ventilation performance of tall buildings with DSFs is dependent on the complex heat transfer and the airflow behavior in the cavity and adjacent indoor spaces. These not easily predictable phenomena are highly informed by the outdoor conditions and the DSF configurations. Accordingly, proper assessment and prediction tools are required to effectively evaluate the feasibility of DSF applications in tall office buildings, as well as the performance of DSFs in the early design stage. If available, full-scale experiments are more desirable than other methods, such as analytical methods, empirical methods, and reduced-scale experiments, since they generate the data closest to reality. Full-scale measurements were conducted to validate computational simulation results in some studies on the performance of DSFs (e.g., Kim et al. 2011; Wen et al. 2017). As a reduced-scale experiment, wind tunnel tests have not been commonly conducted in the studies on DSFs compared to full-scale experiments and computational simulations. Only a few studies (e.g., Hu et al. 2017) investigated the impact of DSF configurations, such as cavity depth and openings, on the distribution of wind pressure over the surfaces of tall buildings with respect to structural aspects.

3.1. CHOSEN RESEARCH METHODOLOGY

Computational Fluid Dynamics (CFD) can be utilized to make comprehensive predictions on natural ventilation in buildings, as it provides the distributions of air velocity, temperature, pressure, and particle concentration. As an evaluation and prediction tool for natural ventilation, the reliability of CFD has been proved in many studies (e.g., Cheung and Liu 2011; Brandl et al. 2014). These studies conducted CFD simulations and validated the CFD results against either data from on-site measurement or experimental measurements available in the literature. CFD simulation is a relatively promising method and widely used in various studies on DSFs. CFD simulations have been conducted to investigate the impact of design parameters of DSFs such as the variations of openings (Nasrollahi and Salehi 2015), cavity width/height (Sanchez et al. 2016), and shading devices (Su et al. 2017). CFD provided various visual and quantified results such as indoor air temperature, indoor air velocity, cavity temperature, airflow rate, and air change rate for these studies depending on what results each study expected to obtain. Once validated, CFD can provide more detailed airflow characteristics on the entire space than experimental methods, which

only provide the data for some points (Omrani et al. 2017). Therefore, the coupling method of CFD and experiments has been commonly used for parametric studies on natural ventilation in buildings with DSFs, as the iterative process in terms of modifying parameters can be conducted in the computational domain after the validation of CFD simulation results against experimental data. Although full-scale experiments generate more realistic data, in this study, wind tunnel tests will be conducted to validate the CFD simulation results, due to the lack of experimental data for the analysis of naturally ventilated tall office buildings (i.e., buildings taller than 200 m) with multi-story DSFs.

3.2. SELECTED CITY AND CLIMATE

Chicago was selected to improve the relevance of this research to practice, as it has more tall buildings than other cities in the world according to CTBUH (CTBUH 2019) (i.e., thirty-seven 200m+ tall buildings in Chicago). Moreover, a few DSFs have been applied only to low and mid-rise buildings in Chicago. Most DSF applications are found in European cities in which there are a few tall buildings, based on the available information from (BestFacade, Japan Sustainable Building Database), online sources (ArchDaily), and studies (Lee et al. 2002; Oesterle et al. 2001; Poirazis 2004). Since the climate of Chicago is classified as Cool-Humid (Zone 5A) (ASHRAE standard 90.1-2010 and 169-2013), Chicago may represent such cities as Boston, New York, and Seoul. According to the State Climatologist Office for Illinois, Chicago's climate is continental with cold winters, warm summers, and moderate spring and fall. Temperature, humidity, cloudiness, and wind direction are frequently fluctuating within a short range. There are several features of the climate of Chicago. The strong winds in Chicago can be experienced between tall buildings. A frequent lake breeze also affects the climate of Chicago. Wind speeds, in central and northeastern Illinois in which Chicago is located, are higher than western, northwestern, and southern Illinois due to the flat and open terrain with barely any trees and hills. More moderate temperatures in spring and fall are the norm in Chicago; on the other hand, wind speeds are higher in spring and winter (State Climatologist Office for Illinois). Therefore, natural ventilation may be more suitable during spring and fall, yet it could be also suitable for some buildings along the shore of Lake Michigan in summer, due to the breeze.

3.3. DESIGN PARAMETERS

There are various design parameters that were already investigated to assess the performance of DSFs. Some key findings related to design parameters are emphasized in some studies on DSFs: the relationship

between cavity temperature and opening size (Gratia and Herde 2007), the recommendations for opening location to improve the airflow throughout the entire building (Nasrollahi 2015 and Salehi 2015), the optimum air cavity width/height to reduce energy consumption in the summer and winter scenarios (Sanchez et al. 2016), the effects of cavity extension on the airflow inside the cavity as the way of preventing reverse flow (Barbosa 2015), the importance of shading devices for the thermal performance of DSFs (Mei et al. 2007), and the impact of glazing type/position on building cooling energy (Chan et al. 2009). The results and conclusions from these studies are helpful for architects to have an initial idea of how DSFs should be conceptualized in the early design stage. Among various design parameters mentioned above, the more fundamental and wind-related components, such as openings, cavities, and segments, are the only ones tested in this study, as wind effect is one of the most important factors for effective natural ventilation in tall office buildings with DSFs.

A 238 m (780 ft) hypothetical tall office building model is developed for this study. The model consists of sixty floors with the floor depth of 36 m (120 ft) and the lease span of 9 m (30 ft). The ratio of building height and depth is preferably 6:1 (Choi 2009). The floor to floor height is 4 m (13 ft) with the ceiling height of 2.7 m (9 ft) in the consideration of the steel structure. Due to the insufficient information on the components of DSFs for tall office buildings taller than 200 m, the range of variations of DSF components is determined based on the existing buildings investigated by Wood and Salib (2013). As it is shown in figure 1, the design parameters such as cavity depth, cavity segmentation, and opening size and location will be tested in the CFD simulation software ANSYS FLUENT. As one of the expected

results in this study, the combined effect of those design parameters on natural ventilation in tall office buildings with DSFs will be discussed, as the parameters affect both stack effect and wind effect, two important driving forces for natural ventilation. Moreover, the results will show which parameter is the most influential in facilitating effective natural ventilation and in optimizing the magnitude of the two driving forces.

3.4. RESEARCH WORKFLOW

As it is shown in figure 2, the workflow consists of several steps with respect to the simulation, the experiment, and the assessment process. CFD is the main tool to simulate the performance of DSF configurations under specific climatic conditions, including outdoor temperature and wind profiles within the atmospheric boundary layer (ABL). Wind tunnel tests will be conducted to simulate the airflow in some configurations and compare the data with the CFD simulation results for validation. Due to the time intensive nature of the simulation process, resulting from the size of the computational domain and the 3D model (i.e., a tall office building with DSFs), the CFD simulation process is divided into three parts, such as 'outdoor simulation', 'indoor simulation—cavity only', and 'indoor simulation—typical floor'. There are basically seventy-two naturally ventilated tall office building models with DSFs to be tested in the CFD simulation. The performance of each configuration will be assessed at the end of the workflow based on the ventilation requirements.

Task 1: Outdoor Simulation

First, a large computational domain is created to simulate outdoor conditions and obtain data as realistic as possible. Since tall buildings dynamically respond to wind according to the characteristics of turbulent flows depending on the height, simulating the whole building with the outdoor conditions in the computational domain is inevitable, in order to reduce the discrepancies between the simulation and the reality (figure 3a). The airflow will be simulated only for the outside of the building to obtain boundary conditions, such as wind velocity and outdoor temperature on the outer skin of DSFs. A few tall office buildings with DSFs will also be physically modeled in accordance with the wind tunnel environment. The CFD simulation results obtained from this first step of the CFD simulation process will be compared with the wind tunnel data only for validation of the impact of the outdoor conditions on the surfaces of the tall office building.

Task 2: Indoor Simulation – Cavity Only

Second, the boundary conditions collected from the first step of the CFD simulation process will be used to

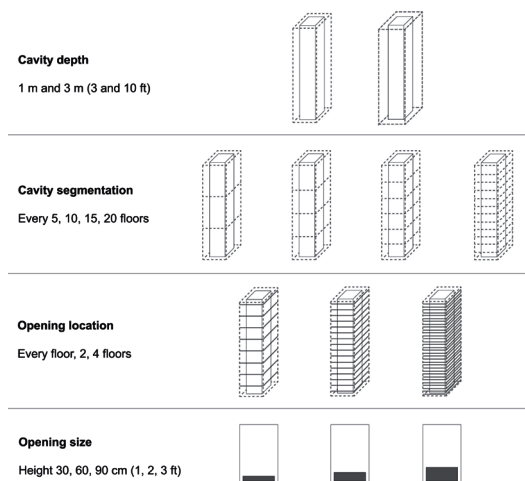


Figure 1: Design parameters and variables defined for simulations. (Author 2019)

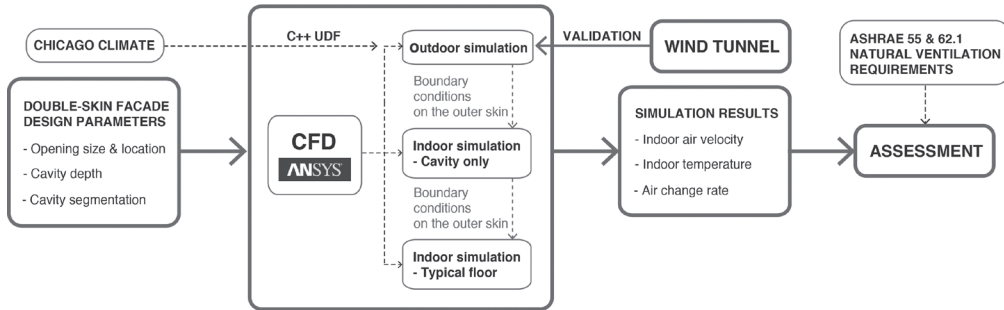


Figure 2: The overall workflow: CFD simulation and wind tunnel test. (Author 2019)

simulate the distributions of velocity and temperature in the cavity, without any air movement between the cavity and the adjacent indoor spaces. Thus, operable windows are not created on the inner skin in this step of the process. As illustrated in figure 3b, the multi-story DSF type was chosen for this study as sufficient vertical force can be used to drive air through the vertically continuous cavity. However, in this study, the cavity is segmented into several zones as the extensive cavity of tall buildings may cause extreme stack flows, due to the height. The objectives in the second task are to (1) preliminarily assess the performance of DSF configurations with respect to the complex airflow characteristics inside the cavity, and (2) obtain all the boundary conditions on the inner skin to simulate the airflow in the indoor spaces as the next step.

Task 3: Indoor Simulation – Typical Floor

Third, the indoor airflow on some typical floors (e.g., one floor within each segment) will be simulated to obtain the detailed information on airflow characteristics

such as the distributions of air velocity and indoor temperature on the floors, and also air change rate based on the airflow through operable windows on the inner skin. For the CFD simulation, only the indoor spaces are created without DSFs (figure 3c), as the external environment and the cavity are already accounted for in the previous simulation steps. In order to investigate the impact of the wind direction and the related pressure on ventilation types such as single-sided and cross-ventilation, the distribution of wind pressure on four-sides of the square floor plan will be simulated simultaneously with different boundary conditions for each side. The performance of each configuration will be assessed based on whether the indoor spaces with each configuration meet the ventilation requirements established in ASHRAE standards: (1) Indoor air velocity should not exceed 0.2 m/s (ASHRAE standard 55-2010), (2) Indoor operative temperature should be within the acceptable range based on the chart, 'Acceptable operative temperature ranges for naturally conditioned spaces' in ASHRAE

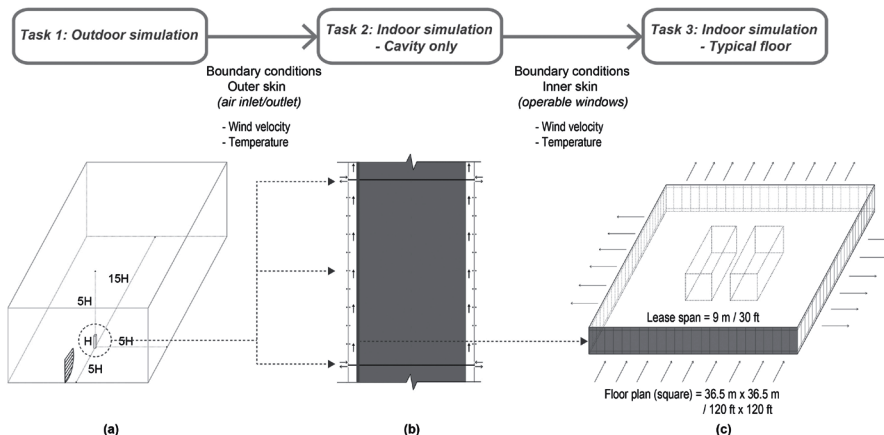


Figure 3: (a) A tall office building with DSFs in the CFD domain, Source: (Franke et al. 2004), (b) one segment, a part of the whole building section with DSFs, and (c) A typical floor plan and the wind direction with positive and negative pressure. (Author 2019)

The Feasibility of Natural Ventilation in Chicago's Tall Office Buildings Using Double-Skin Façades

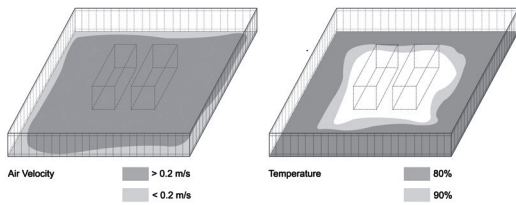


Figure 4: An example of visualized air velocity and temperature distributions. (Author 2019)

standard 55-2010, and (3) Air change rate is required to be 6-8 exchanges per hour (ASHRAE standard 62.1-2013). After the assessment of the DSF configurations and the interpretation of the results based on the criteria, some more configurations with modified design parameters may need to be tested again from the second step of the CFD simulation process to find better configurations for the indoor airflow behavior. The possible variations of lease span will be also discussed in this task, based on the simulation results.

4. EXPECTED OUTCOMES

The CFD simulation is currently being conducted to obtain the results and key findings. Thus, at this point, the expected results from both the CFD simulation and the wind tunnel test are discussed in this section. This research is expected to produce the following: (1) the visualized distributions of air velocity and indoor temperature at 1.2 m and 1.8 m above the floor (i.e., occupied zone) to determine the acceptability of thermal comfort and the effectiveness of natural ventilation in the indoor spaces (figure 4), (2) the most proper double-skin façade (DSF) configuration with quantified natural ventilation performance to facilitate effective natural ventilation in tall office buildings in Chicago and other cities that have similar climatic conditions, (3) the maximum number of natural ventilation hours throughout the year in Chicago, (4) a performance

based DSF design guideline, for the design of openings, cavities, and segments, which can be used in the early design stage, (5) the reasonable lease span of tall office buildings for effective natural ventilation, and (6) the suitable proportion between the magnitude of stack effect and wind effect inside the cavity depending on the height (e.g., a comparison between the proportion in the cavity near lower floors and higher floors).

5. CONCLUSIONS

The conclusions are expected to address the feasibility of natural ventilation in Chicago's tall office buildings, by means of DSFs, which currently highly rely on mechanical systems. As one of the expected results, the proper DSF configurations will lead to a better understanding of how DSFs should be designed not only to facilitate effective natural ventilation, but also to improve thermal comfort in indoor spaces under the specific climatic conditions in Chicago. The performance-based DSF design guideline will help architects and designers make decisions in the early design stage when passive strategies should be discussed, as they significantly affect building forms, structures, materials, and systems. Further insight on the airflow behavior in Chicago's tall office buildings with DSFs will enable one to specifically determine the size and the location of DSF components for each floor, based on different magnitudes of stack and wind effect. Although the energy performance of tall office buildings with DSFs is not quantified in this study, the application of natural ventilation is expected to improve the energy performance by reducing the load on HVAC systems. Despite the large number of tall office buildings, DSFs have not been applied to any tall office buildings in Chicago, due to the initial construction costs, additional maintenance costs, the loss of rentable space, and structural loads, etc. However, if proved, the benefits of DSFs for natural ventilation, energy performance, and thermal comfort may compensate for the disadvantages.

REFERENCES

- ArchDaily. 2018. "Kraanspoor / OTH Architecten." Accessed November 2020. <https://www.archdaily.com/2967/kraanspoor-oth-ontwerpgroep-trude-hooykaas-bv>
- ArchDaily. 2013. "Queen Elizabeth II Courts of Law / Architectus + Guymer Bailey Architects." Accessed November 2020. <https://www.archdaily.com/425111/queen-elizabeth-ii-courts-of-law-architectus-guymer-bailey-architects>
- ASHRAE Standard 55-2010. 2010. *Thermal Environmental Conditions for Human Occupancy*. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.
- ASHRAE Standard 62.1-2013. 2013. *Ventilation for Acceptable Indoor Air Quality*. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.
- ASHRAE Standard 90.1-2010. 2010. *Energy Standard for Buildings Except Low-Rise Residential Buildings*. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.
- ASHRAE Standard 169-2013. 2013. *Climatic Data for Building Design Standards*. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

BestFacade. Accessed at <http://www.bestfacade.com/>

Brandl, D., T. Mach, M. Grobbauer, and C. Hochenauer. 2014. "Analysis of Ventilation Effects and the Thermal Behavior of Multifunctional Façade Elements with 3D CFD Models." *Energy and Buildings* 85: 305-320.

Chan, A. L. S., T. T. Chow, K. F. Fong, and Z. Lin. 2009. "Investigation on Energy Performance of Double Skin Façade in Hong Kong." *Energy and Buildings* 41: 1135-1142.

Cheung, J., and C. H. Liu. 2011. "CFD Simulations of Natural Ventilation Behavior in High-Rise Buildings in Regular and Staggered Arrangements at Various Spacings." *Energy and Buildings* 43: 1149-1158.

Cho, J.S. 2007. "A Study of Form Composition and Efficiency in High-Rise Office Buildings." *Journal of the Architectural Institute of Korea* 23, no. 6: 33-40.

Choi, H.S. 2009. "Super Tall Building Design Approach." *Proceedings of The American Institute of Architects Continuing Education Systems Program*.

CIBSE (Chartered Institution of Building Services Engineers). 2005. *Natural Ventilation in Non-Domestic Buildings*. Applications Manual AM10.

Council on Tall Buildings and Urban Habitat (CTBUH). 1995. *Architecture of Tall Buildings*. Pennsylvania: McGraw-Hill.

Council on Tall Buildings and Urban Habitat (CTBUH). 2019. Accessed at <http://www.skyscrapercenter.com>, *The Global Tall Building Database of the CTBUH*.

Etheridge, D., and B. Ford. 2008. "Natural Ventilation of Tall Buildings – Options and Limitations." *CTBUH 2008 8th World Congress*, Dubai.

Fisk, W.J., D. Black, and G. Brunner. 2012. "Changing Ventilation Rates in U.S. Offices: Implications for Health, Work Performance, Energy, and Associated Economics." *Building and Environment* 47: 368-372.

Franke, J., C. Hirsch, A. Jensen, H. Krüs, M. Schatzmann, P. Westbury, S. Miles, J. Wisse, and N. G. Wright. 2004. "Recommendations on the use of CFD in Wind Engineering, COST Action C14: Impact of Wind and Storm on City Life and Built Environment." *von Karman Institute for Fluid Dynamics*.

Gratia, E., and A. D. Herde. 2007. "Greenhouse Effect in Double-Skin Façade." *Energy and Buildings* 39: 199-211.

Hu, G., S. Hassanli, K. G. S. Kwok, and T. K. Tse. 2017. "Wind-Induced Responses of a Tall Building with A Double-Skin Façade System." *Journal of Wind Engineering & Industrial Aerodynamics* 168: 91-100.

Japan Sustainable Building Database. Accessed at <http://www.ibec.or.jp/jsbd/>

Jordana, Sebastian. 2012. "Cleveland Clinic Abu Dhabi / HDR." *ArchDaily*. Accessed November 2020. <https://www.archdaily.com/292167/in-progress-cleveland-clinic-abu-dhabi-hdr-architecture>

Kim, Y., J. Lee, S. Kim, and S. Kim. 2011. "Effects of Double Skin Envelopes on Natural Ventilation and Heating Loads in Office Buildings." *Energy and Buildings* 43: 2118-2126.

Larsen, S. F., L. Rengifo, and C. Filippin. 2015. "Double Skin Glazed Facades in Sunny Mediterranean Climates." *Energy and Buildings* 102: 18-31.

Lee, E., S. Selkowitz, V. Bazjanac, V. Inkarojrit, and C. Kohler. 2002. "High-Performance Commercial Building Façades. Building Technologies Program." *Environmental Energy Technologies Division, Ernest Orlando Lawrence Berkeley National Laboratory (LBNL)*, University of California, Berkeley, USA (LBNL - 50502).

Li, J. 2012. "Advanced Supertall Building Design in Hot-Summer and Cold-Winter Climates." *CTBUH 2012 9th World Congress*.

Mei, L., D. Loveday, D. Infield, V. Hanby, M. Cook, Y. Ji, M. Holmes, and J. Bates. 2007. "The Influence of Blinds on Temperatures and Air Flows within Ventilated Double-Skin Façades." *Proceedings of Clima 2007 WellBeing Indoors*. University of Salford.

Montazeri, H., and F. Montazeri. 2018. "CFD Simulation of Cross-Ventilation in Buildings Using Rooftop Wind-Catchers: Impact of Outlet Openings." *Renewable Energy*, 118: 502-520.

Nasrollahi, N., and M. Salehi. 2015. "Performance Enhancement of Double Skin Facades in Hot and Dry Climates Using Wind Parameters." *Renewable Energy* 83: 1-12.

Omrani, S., V. Garcia, B. Capra, and R. Drogemüller. 2017. "Natural Ventilation in Multi-story Buildings: Design Process and Review of Evaluation Tools." *Building and Environment* 116: 182-194.

Oesterle, E., R. D. Lieb, M. Lutz, and W. Heusler. 2001. *Double Skin Facades – Integrated Planning*. Munich: Prestel Verlag.

Poirazis, H. 2004. "Double-Skin Façades for Office Buildings – Literature Review." *Division of Energy and Building Design Department of Construction and Architecture*, Lund University.

Sanchez, E., A. Rolando, R. Sant, and L. Ayuso. 2016. "Influence of Natural Ventilation due to Buoyancy and Heat Transfer in the Energy Efficiency of a Double Skin Façade Building." *Energy for Sustainable Development* 33: 139-148.

Sev, A., and G. Aslan. 2014. "Natural Ventilation for the Sustainable Tall Office Buildings of the Future." *International Journal of Architectural and Environmental Engineering* 8: 854-866.

The Feasibility of Natural Ventilation in Chicago's Tall Office Buildings Using Double-Skin Façades

State Climatologist Office for Illinois. Accessed at <https://www.isws.illinois.edu/statecli/general/chicago-climate-narrative.htm>

Su, Z., X. Li, and F. Xue. 2017. "Double-Skin Façade Optimization Design for Different Climate Zones in China." *Solar Energy* 155: 281-290.

Sundell, J., H. Levin, W. W. Nazaroff, W. A. Cain, W. J. Fisk, D. T. Grimsrud, F. Gyntelberg, Y. Li, A. K. Persily, A. C. Pickering, J. M. Samet, J. D. Spengler, S. T. Taylor, and C. J. Weschler. 2011. "Ventilation Rates and Health: Multidisciplinary Review of the Scientific Literature." *International Society of Indoor Air Quality and Climate* 21 (3): 191-204.

The United Nations. 2018. "2018 Revision of World Urbanization Prospects." Department of Economic and Social Affairs.

U.S. Energy Information Administration (EIA). Accessed at <https://www.eia.gov/>

Wen, Y., Q. Guo, P. Xiao, and T. Ming. 2017. "The Impact of Opening Sizing on the Airflow Distribution of Double-skin Façade." *10th International Symposium on Heating, Ventilation and Air Conditioning*, Jinan, China, Procedia Engineering 205: 4111-4116.

Wong, P. C., D. Prasad, and M. Behnia. 2008. "A New Type of Double-Skin Façade Configuration for the Hot and Humid Climate." *Energy and Buildings* 40: 1941-1945.

Wood, A., and R. Salib. 2013. *Natural Ventilation in High-Rise Office Buildings*. Chicago: Council on Tall Buildings and Urban Habitat.

A CRITICAL INQUIRY INTO THE 'PROBLEM' OF STOPPING IN ARCHITECTURE'

Skender Luarasi
POLIS University

Abstract: "Self-driving Uber Car Kills Pedestrian in Arizona, Where Robots Roam," reads a *New York Times* article of March 19th, 2018, one day after the accident. The fundamental problem of artificial intelligence has always been how the robot stops; not how to make the robot walk, say "Hello!" or "Good Morning!"; do things so complicated as to make us mumble in awe: "Wow!", but rather how *not* to act, how *not* to say "Hello!" at the right, or rather wrong moment. What is this moment? How can it be found? This paper asks such questions in the context of design and architecture: How does architecture stop? How do we close a design process, or choose among different design variations? Such concern for stopping has persisted in history, even if it has been eclipsed by what could be called, perhaps redundantly, *the ideology of self-generation*. Architects are always busy discoursing about generation, how architecture should come about, *by itself, NOW!* Upon close inspection, however, we find that the *desire* for stopping has been there all along, creeping from between the building blocks of architecture, undermining the absolutism of self-generation. From the projectiles of Vitruvius foundering in mud to the 'hermaphrodite' forms of Ronchamp, and today, in our deceptively fluid digital age, there are architects who have paid as much attention to stopping as they have to generation. The paper highlights instances of stopping in history, from Perrault to Paul Valéry and the digital.

Keywords: Stopping, design, generation, knowledge, architecture

INTRODUCTION

"We think in generalities, but we live in detail." (Whitehead 1926, 192)

How does architecture stop? How do we make design choices? How was such a question addressed in the past? One of those fascinated with stopping was Paul Valéry, a thinker whose aesthetics intersected with Le Corbusier's, yet one who is either misunderstood or rarely mentioned in architectural discourse.² Valéry was fascinated with seashells, how their form stops through a "combination of rhythm and indivisible movement."

But suddenly an end must come. This strange torsion must cease, the nacre on the inside and the coarser covering must join, and the distinction between the two substances of the shell must vanish or explain itself, while at the same time its form must be completed by some decision that remains to be arrived at . . . The architect knows only his rule and square. The musician does pretty much as he pleases. The poet proceeds by leaps and bounds. But nature has preserved her cautious methods, the inflection in which she envelops her changes of pace, direction, or physiological function. She knows how to finish a plant, how to open nostrils, a mouth, a vulva, how to create a setting for an eyeball; she thinks suddenly of the sea shell when she has to unfold the pavilion of an ear, which she seems to fashion the more intricately as the species is more alert. (Valéry 1977, 111-112; italics added).

Architects have come a long way from the rule and square. Today, with the aid of digital technologies, one can generate forms with a complexity and speed unimagined up until three decades ago. Yet it is precisely today that the question of stopping erupts with full force: *Where do you stop? How do you select the best*

out of hundreds of iterations? While the answers vary, they all share the ethos and hubris in thinking that one *can* and *ought* to provide an answer to such question; they all frame stopping as a *problem of knowledge*, one that demands principles or criteria *NOW!* for a process whose closure, in Valéry's terms, is enabled by a *delayed* decision ... *Stopping is an event that is found in (a) process, rather than an epistemological problem that can be solved, in general. Yet knowledge as an epistemic domain at a particular historical moment matters insofar as it demands and structures the way we endeavor to provide an impossible answer to the 'problem' of stopping. While stopping is structured by such demand, it is always found outside the domain of knowledge.*

1. THE NATURAL VERSUS THE CUSTOMARY

The question of stopping precedes the digital. It is asked most urgently at those moments of breaks and crisis, but also liberation, that define modernity. For example, the 17th century's *querelle* between François Blondel and Claude Perrault on whether certain proportions were transcendently or empirically beautiful is one such moment. What is at stake in this debate is nothing other than the question of *knowing* where and how to stop at the very moment of a shift of emphasis from inherited knowledge to one constructed or generated by the subject.³ Perrault's ingenious 'solution' to the 'problem' was to provide both a constant and variable concept, or a positive and arbitrary beauty. If the former is "very apparent and consists in the relationship the parts have

collectively as a result of the balanced correspondence of their size, number, disposition, and order," the latter was what "appears agreeable not by reasons within everyone's grasp but merely by custom and the association the mind makes between two things of a different nature" (Perrault 1993, 40-51).

Perrault's theory has a double 'fail-safe' feature: on the one hand, the eye of the mind can *positively* recognize the beauty of proportions. If the eye fails (to stop...), then the empirical tradition corrects our judgment through a (potentially infinite) table of proportional values developed over time. However, as Rudolf Wittkower recognized, this doubling of judgement opens up the door toward relativism. In *Architectural Principles* he lamented that proportions had become infinite: "*Les proportions, c'est l'infini* – this terse statement is still indicative of our approach" (Wittkower 1971, 153). Albeit, Wittkower contributed himself to such relativization, when he described the Palladian Villas as customary variation governed by a positive knowledge: geometry.

In "The Mathematics of the Ideal Villa," Rowe *discerns* the same geometrical ghost underlying Palladio's Villa Malcontenta and Le Corbusier's Villa Stein at Garche.⁴ He argues that in Malcontenta the plan exhibits 'natural' beauty through its abstract shape, while the facades exhibit 'customary' beauty through the Ionic order. At Garche it is the facades that exhibit the 'natural' as "virtues of a mathematical discipline," while the plan demonstrates the ambiguous 'customary' beauty: the 'arbitrary' free movement, curved walls and framed views (Rowe 1976, *Ibid.*, 9). Here, the design choice or stopping belongs to the 'customary', while it is held in check, as it were, by the 'natural'.⁵ Aldo Rossi proposed a similar distinction between typology as natural and constant and morphology as customary and variable (Rossi, 1982, 116). Alan Colquhoun distinguished between *form* which applies to "a configuration with natural meaning or none at all," and *figure* which refers to "a configuration whose meaning is given by culture" (Colquhoun, quoted by Peter Rowe, 1994, 177). Though less explicitly, Greg Lynn saw the spline as natural insofar it was generalized by a topological continuity, and the baroque curve as *only* customary insofar as it consists of "segments of multiple discrete radial elements." (Lynn 1999, 20).

In *Design Thinking* Peter Rowe subsumes stopping under "a *problem space* [with] *knowledge states*, some of which represent solutions to a problem" (Rowe 1994, 51) This 'natural' is represented as a tree whose nodes are stopping points. But where does the tree metaphor stop?⁶ In *Design Thinking in Digital Age* Rowe, while arguing (or hoping?) that the digital provides "a clearer view of suitable stopping rules" he also provides the

disclaimer that "there is no in-principle guarantee that this would be the case" (Rowe, 2017, 59).⁷ One can stop only on the level of detail and the customary. Why is stopping not possible from with-in knowledge?

2. VALÉRY AND EUPALINOS

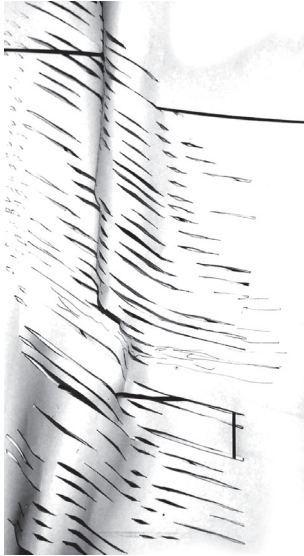
That is, Valéry answers, because there is "no way to measure knowledge except by the real powers it confers. *I know only what I know how to handle*" (Valéry 1977, 126). *The object of representation is already the representation of the object.* The 'problem' of not knowing where to stop is our knowledge's freedom to produce representation of objects in respect to form: "If I have undertaken to produce one particular form, it is because I could have chosen to create entirely different ones . . ." (Valéry 1977, 120-121). Elsewhere, Valéry writes that we can stop only by acting "directly on the freedom of the system of our *esprit* ... we simply wait for the desired effect to present itself ... we can do nothing but wait. *We have no means to achieve in ourselves exactly what we want to obtain*" (as cited in Guerlac 1997, 102). What does this 'waitingwait' entail?

Eupalinos or the Architect provides a way out of this infinite variation. Often misunderstood as a celebration of Platonic thought the play provides an inversion of such thought.⁸ Socrates, uncharacteristically cast with doubt for a man who presumably knew everything, is eternally damned to wonder like a ghost without finding its body, its closure, its finitude, without knowing where to stop. He is 'paying for his sin', which, to paraphrase Nietzsche vis-à-vis Derrida, is the sin of never having written.⁹ The book is a passage from Socrates to Eupalinos, from the thinker to the maker, from geometry as an idea in the mind to a geometry mediated by objects and techniques. Phaedrus confronts Socrates with the story of a maker "of a strange versatility" who

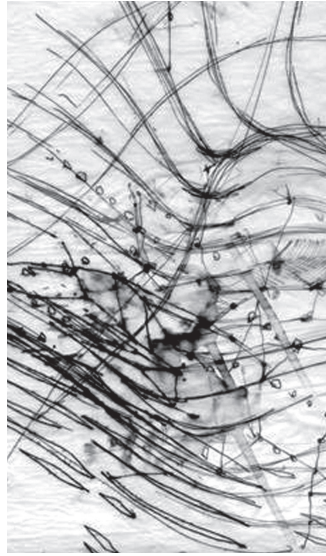
thought that a ship should . . . be created by the knowledge of the sea, and should almost be fashioned by the very wave itself! . . . He sought therefore for the form a hull should have if the bottom was to remain more or less constant, whether the ship rolled from side to side – or danced in any other way about some center . . . He would draw strange figures which for him made visible the secret properties of his float; but for my part I could see in them nothing in the least like a ship. (Valéry 1932, 82-83).

Through these 'strange' figures the constructor would try to

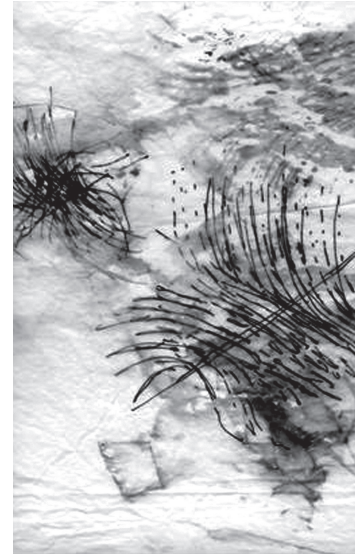
imitate the perfection of the swiftest fishes . . . their *fishy thoughts* . . . steering towards their destiny according to whim; and then their live mastery in the heart of storms! It was as though he himself felt their well-adapted forms conducting from head to tail, by the quickest way, the waters which lie in front of them, and which must be put behind them that they may advance . . . (Valéry 1932, 83-84, italics added)



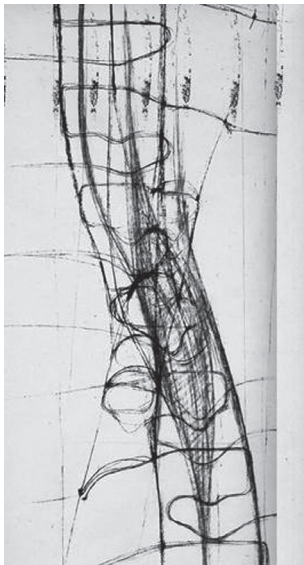
Process: Paper model



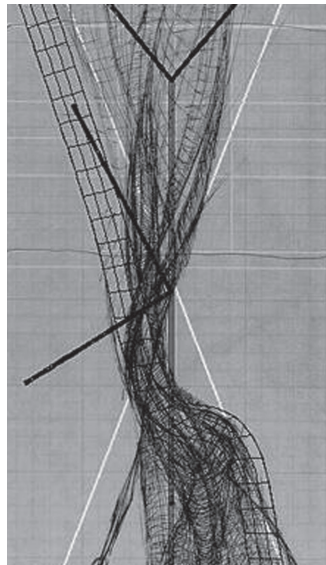
Process: Paper model & Drawing



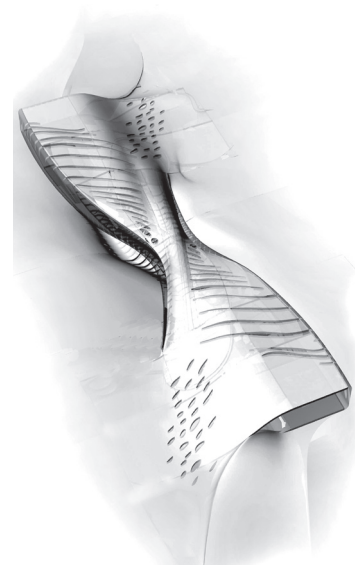
Process: Digital modeling & drawing



Process: Watercolor & drawing



Process: Watercolor & drawing



Process: Digital modeling & drawing

Figure 1: *House for Two Strangers*, designed by Skender Luarasi 2003

The design process is a *dis*-position or tendency that progresses in and through obstacles:

if no obstacle impedes your progress, progress is quite impossible . . . once the necessary obstacle is present, it works against you; it drinks up your fatigues, parsimoniously metes out to you space in time. *Here the delicate act of the artist intervenes in the choice of a form: for the form has to take from the obstacle what it requires in order to advance, but must only take what least checks the mover.* (Valéry 1932, 84, italics added).

Valéry's conclusion is that knowledge can only be measured by powers outside itself. One can know through what one does not know how to handle. One can stop not when knowledge abstracts obstacles but only when obstacles abstract knowledge.

3. A HOUSE FOR TWO STRANGERS

The project *A House for Two Strangers* is shown below as an example a design process marked by

A Critical Inquiry into the 'Problem' of Stopping in Architecture

intercalated moments of stopping. This process is not a 'construction tree' with 'knowledge states', but rather a chain of obstacles *entrenched* into one another. Each of these states is either a potential stopping moment or another rhizomatic bifurcation. The variable curvature is actualized with different digital and analogue techniques which perform as obstacles of one another: paper, pencil drawing, watercolor, photoshop, physical models and digital modeling. The project, which is based on Samuel Becket's *Waiting for Godot*, folds around a path that is doubled in the exterior and the interior. The path connects the spaces of the two main characters of the play, while also connecting the house to that outside from which Godot is expected to arrive. Vladimir and Estragon wait for Godot, but *God-ot* never appears. Godot's absence, which is necessarily infinite, triggers a *toggling* process between the two, one that yields closure for the two tormented souls (figure 1).

CONCLUSION

How does the increase in computational speed affect stopping? It is more difficult to stop in a digital

context because, to paraphrase Valéry, the non-relation between form requirements such as material and size increases. This liberation of form is similar to André Leroi-Gourhan's rather 'scandalous' argument about the liberation of hands from locomotion and nourishment, a liberation that privileged gesture and speech, and consequently the evolution of the brain. The latter "was not the cause of developments in locomotory adaptation but their beneficiary" (Leroi-Gourhan 1993, 26). *The more developed the technology is, the 'blinker' the page is, less criteria to justify form there are; freer our mind and hands are; more difficult it is to stop; more relevant the question of stopping becomes.* What new 'brain' does this liberation call? If we are on the verge of a "homo cyberneticus" relieved from the task of remembering (Cache 2011, 24), then what will this liberated brain be capable of thinking? In order to see whether such forecast is a tendency in the making or just an illusion, further research of the design processes must be undertaken, particularly by emphasizing stopping in its own terms and conditions, in terms of a non-relation with generation.

ENDNOTES

- 1 This paper has emerged from my dissertation "Where Do You Stop? A Critical Inquiry into Style, Geometry and Parametricism in History," received at Yale University in 2018. It is also a snapshot of the emerging introduction of my future book: *On the Art of Stopping: A Critical Inquiry into the Problem of Stopping in the work of Le Corbusier*, which is currently in progress.
- 2 Niklas Maak is one of the few to provide an authoritative account on the relationship between Paul Valéry and Le Corbusier's work. (See: Maak, 2011)
- 3 On the relationship between knowledge as generation and modernity see: Helmut Muller-Sievers, *Self-Generation: Biology, Philosophy, and Literature Around 1800*, (Stanford: Stanford University Press, 1997). On the relationship between modern knowledge as construction and geometry see: David Rapport Lachterman, *The Ethics of Geometry: A Genealogy of Modernity*, (New York: Routledge, 1989). For a reference of these texts in architectural discourse see: Detlef Mertins, "Bioconstructivisms," in *Modernity Unbound*, (London: Architectural Association Publications, 2011), p. 161.
- 4 Anthony Vidler has argued that if Wittkower uses geometry to construct the historical object, then Rowe uses it to construct the "post-modernist object" (Vidler 2013, 79).
- 5 Vidler has argued that Rowe's framework would stand "both as the model for design approach, as in the work of the New York Five, and as the paradigm for contemporary formalism to work against, as in the digital practices of Greg Lynn" (Vidler 2008, 86). It can be shown, however, that digital practices rely and expand on such model.
- 6 One of the reviewers of this paper commented that "trees are not metaphors but are parts of mathematical structures of lattices, partial orders, posets, chains, etc." I use the term metaphor in the strict sense of the *model*. On the topic of metaphors and models see: Max Black's *Models and Metaphors*, 219-243, and Paul Ricoeur's *The Rule of Metaphor*, 239-246. The argument is that "with respect to the relation to reality, metaphor is to poetic language what model is to scientific language (Ricoeur, 1977, 240).
- 7 I explore this topic the question of stopping in more detail in: "Making the Donkey Drink Water: An Inquiry into the 'Problem' of Stopping in the Digital Age," in *[Un]Timely Architecture*, edited by Ingrid Mayrhofer-Hufnagl, to be published by Transcript in 2020.
- 8 As Niklas Maak correctly points out, *Eupalinos* "embodies an ironical approach typical of its author, using a Platonic dialogue to oppose Plato" (Maak 2011, 121).
- 9 Jacques Derrida quotes Nietzsche: "Socrates, he who does not write," in *Of Grammatology*, trans Gayatri Chakravorty Spivak (Baltimore: The John Hopkins University Press, 1974), p. 6

REFERENCES

- Black, Max. 1962. *Models and Metaphors*. Ithaca: Cornell University Press.
- Cache, Bernard. 2011. *Projectiles*. London: AA Publication.
- Colquhoun, Alan. 1978. "Form and Figure." *Oppositions* 12 (Spring): 29-37.
- Guerlac, Suzanne. 1997. *Literary Polemics: Bataille, Sartre, Valéry, Breton*. Stanford: Stanford University Press.
- Le Corbusier. 1957. *The Chapel at Ronchamp*. Translated by Jacqueline Cullen. London.
- Le Corbusier. 1987. *The Decorative Art of Today*. Translated by James I. Dunnet. Cambridge: MIT Press.
- Le Corbusier. 1958. *Modulor 2: Let the User Speak Next*. Translated by Peter de Francia and Anna Bostock. Cambridge: MIT Press.
- Leroi-Gourhan, André. 1993. *Gesture and Speech*. Translated by Anna Bostock Berger. Cambridge: MIT Press.
- Lynn, Greg. 1999. *Animate Form*. New York: Princeton Architectural Press.
- Maak, Niklas. 2011. *Le Corbusier: The Architect on the Beach*. Munich: Hirmer Verlag
- Perrault, Claude. 1993. *Ordonnance: Ordonnance for the Five Kinds of Columns after the Method of the Ancients*. Translated by Indra Kagis McEwen. Santa Monica: Getty Center
- Ricoeur, Paul. 1977. *The Rule of Metaphor: Multi-disciplinary Studies of the Creation of Meaning in Language*. Translated by Robert CZzerny, Kathleen McLaughlin and John Costello, sj. Toronto, Buffalo. London and Toronto: University of Toronto Press.
- Rossi, Aldo. 1982. *The Architecture of the City*. Translated by Diane Ghirardo and Joan Ockman. New York: IUAS, Cambridge: MIT Press.
- Rowe, Colin. 1976. "The Mathematics of the Ideal Villa." In *The Mathematics of the Ideal Villa and Other Essays*. Cambridge: MIT Press.
- Rowe, Peter. 1994. *Design Thinking*. Cambridge: MIT Press.
- Rowe, Peter. 2017. *Design Thinking in the Digital Age*. Cambridge: Harvard University and Sternberg Press.
- Valéry, Paul. 1932. *Eupalinos or the Architect*. Translated by William McCausland Stewart. Oxford: Oxford University Press.
- Valéry, Paul. 1977. "Man and the Sea Shell." In *Paul Valéry: An Anthology*, edited by James R. Lawler and Jackson Mathews, 108-135. London: Routledge.
- Vidler, Anthony. 2008. *Histories of the Immediate Present: Inventing Architectural Modernism*. Cambridge: MIT Press.
- Whitehead, A. N. 1926. "The Education of an Englishman" in *The Atlantic Monthly*, Vol. 138: 192-198.
- Wittkower, Rudolf. 1971. *Architectural Principles in the Age of Humanism*. New York: Norton.

THE MICROGEOGRAPHIES OF SOCIAL JUSTICE: Architect(ure) and Social Housing

Kourosh Mahvash
University of Waterloo

Abstract: This paper outlines the preliminary framework for the author's doctoral studies in urban planning, which aims to be an academic critique and investigation of the role of architecture, as a practice, and architects, as professionals, in the current status of social housing development. Based on an evolving and expanding literature review, the discussions are framed in three broader categories of 'premise', 'context' and 'investigation'. The study would be primarily *premised* on the notions of the necessity of decommodification of housing and Lefebvre's "Right to the City". Within such preliminary and broad conceptual framework, the study then proposes positioning the research within its socio-political and architectural contexts. While the former is represented by neoliberalism, the currently predominant ideology and driving force behind the majority of governments' decisions and policies all over the world, the latter limits the study to social housing as the architectural manifestation of social justice in the contemporary city. For further contextualization as well as proper-feasible-examination of how state policies have evolved, social housing development and government's attitudes towards it would be examined more thoroughly in the Canadian context. The Canadian case study would delineate how capitalist and neoliberal ideologies have been applied in a geographically and socio-politically specific context. To complete the roadmap for the study, it is then proposed to critically *investigate* the role of architects and architecture in the process of social housing production. The hypothesis is that architectural practice is so tightly entangled with capital that architects have been reduced to mere facilitators of the neoliberal modes of production of space and, in doing so, have knowingly or unwittingly deprived architecture from being a powerful aesthetic, experiential and morphological tool for the manifestation and embodiment of social justice in the city.

Keywords: Architecture, right to the city, social housing, capitalism, neoliberalism

INTRODUCTION

Housing means many things to different groups. It is home for its residents and the site of social reproduction. It is the largest economic burden for many, and for others a source of wealth, status, profit, or control. It means work for those who construct, manage, and maintain it; speculative profit for those buying and selling it; and income for those financing it. It is a source of tax revenue and a subject of tax expenditures for the state, and a key component of the structure and functioning of cities. (Madden and Marcuse 2016, 11)

Just as housing could mean "many things to different groups," it has also been the subject of research in many fields and disciplines, academic or otherwise, and from a variety of perspectives. The wealth of information on the topic is both an opportunity and a challenge: opportunity, as it provides a solid foundation for research on the subject, but also challenging as it seems many areas of research in the field have already been exhausted. Building on the richness, depth and breadth of the preceding thought, inquiry and research in the area, this paper would be an attempt to develop an outline for a line of inquiry into the issue of housing that will eventually make a contribution, however small, to the knowledge we have already accumulated over the years.

To establish a meaningful and hopefully useful research roadmap, this paper has been divided into multiple sections; namely: 'Introduction', 'Premise', 'Context', 'Investigation' and 'Discussion and Conclusion'. The current section, 'Introduction', continues with a clarification on the focus of the research as it relates to housing and the questions it could ask. It is followed by the section titled 'Premise', which describes the overall theoretical position of the research. The next section, 'Context', will then try to contextualize the research from a politico-economical perspective (capitalism/neoliberalism) and through an examination of geographically specific application of capitalist/neoliberal ideology to a distinct context (Canada). The section titled 'Investigation' focuses on the critical evaluation of the subject of the research inquiry, that is, architecture and architects. The paper concludes with outlining the core question of the research followed by a re-examination of architecture and the barriers preventing architects from making a meaningful contribution to the design and development of social housing.

'SOCIAL' HOUSING

Referencing Madden and Marcuse (2016), this paper considers housing primarily as "home for its residents and the site of social reproduction" (11) and excludes the other meanings of housing they have outlined.

This research also takes a 'moral' position based on which access to decent housing should be considered a universal right. While it will be further elaborated in the following section, a central premise of the research is rejecting the concept of housing as commodity and property. This is because, as Madden and Marcuse (2016) assert, as long as housing is considered a commodity, its availability is subject to the rules of the market and the buying power of the actors within it. This, they state, is in contradiction with the universal need for housing, since the ability to buy is obviously not equal and, in the case of those in the dire need of housing, actually non-existent.

There are already viable options for non-market housing; perhaps the most well-known example is the co-operative model. Rental housing could also be an alternative to the commodity-centred market housing provided the landlord is either a co-operative, non-profit organization or public entity with no financial or political agenda.

In his review of housing in Canada, Sewell (1994) has provided an extensive account of various types of housing, including social housing. He very clearly differentiates public housing from other types by defining it as having to meet "two criteria: it is housing owned by a government or government agency; and rent paid on all units is calculated according to household income" (132). He also uses the term "social housing" for non-profit housing and clearly differentiates it from "both market housing and government-controlled public housing". He lists the "characteristics" of social housing as follows:

- "It is not built for profit, but for social reasons."
- "Financial support comes from government, and without that projects would not be viable in the first instance."
- "Housing projects are generally conceived and delivered by groups of people interested in meeting housing needs, not by a company that has lined up a number of financial backers and investors."
- "Project management is usually hands-on and tailored to the target resident profile; in the case of co-op housing, management is resident-controlled" (163).

'Social housing' as referred by this paper would be a model based on either Sewell's definitions of "public housing" and "social housing" or a hybrid model combining the characteristics of the two. The key is that, regardless of the tenure, it would have to be non-market housing which cannot be exchanged as a commodity; it

would be home, as Christopher Alexander asserted, and where the ownership is on control not finance:

Do everything possible to make the traditional forms of rental impossible, indeed, illegal. Give every household its own *home* [emphasis added], with space enough for a garden. Keep the emphasis in the definition of *ownership on control, not on financial ownership*. [emphasis added]. (Alexander, Ishikawa and Silverstein 1977, 395-396 in Sewell 1994, 56)

The emphasis on the universal right to housing while rejecting the notions of private property and housing as commodity are the core premises of this research. The following section further expands on these notions.

1. PREMISE

Madden and Marcuse (2016) argue that, as a result of the "interlocking processes of deregulation, financialization, and globalization," housing has never been as commodified as it is today (36). Despite the prominence of the notion of 'housing as commodity', this research is based on an approach that sees not only its focus of study, social housing, but in fact housing in general outside the circuits of market and capital. It is based on the premise that housing should be disentangled from the web of capitalist notions of private property and commodity. It is also premised on the notion of providing, in Lefebvre's (1996) words, a place of "inhabitation" most importantly for those who have been socially and economically disadvantaged by the processes of capitalism and under the umbrella of free market values.

1.1. DECOMMODIFICATION

Private property has made us so stupid and one-sided that an object is only ours when we have it—when it exists for us as capital, or when it is directly possessed, eaten, drunk, worn, inhabited, etc.,—in short, when it is used by us In place of all these physical and mental senses there has therefore come the sheer estrangement of all these senses – the sense of having. (Marx 1844, in Sklair 2017)

In almost two centuries since Marx's vehement statement in 1844, the notion of private property has only gained momentum under capitalism and its relentless promotion of consumerism. The result is that private property is such a ubiquitous concept and so enshrined in today's culture that according to Sklair (2017) it has made "people believe that human worth is best created and happiness best achieved in terms of consumption and possessions" (225).

Perfectly dovetailing with consumerism is commodification, the other fundamental tenet of capitalist ideology. Madden and Marcuse (2016) define commodification as "the general process by which the economic value of a thing comes to dominate

its other uses." Maintaining that housing has been entrapped within the process of commodification, they postulate that as a result the financial value of housing has utterly eclipsed its use as a place of living, as home (17). The authors also believe that we are struggling with a housing crisis because of the "basic characteristic of capitalist spatial development [that] housing is not produced and distributed for the purposes of dwelling for all; [rather] it is produced and distributed as a commodity to enrich the few" (10). Their characterization of "capitalist spatial development" as the cause of today's housing crisis is supported by Lefebvre's (1996) observation that:

There is a contradiction between the need to organize space according to the demands of society and private property which is increasingly in conflict with collective interests. (211)

With "collective interests" and the public good as the most fundamental aspirations of this research project, it would then seem logical to address the issues of housing, in general, and social housing, in particular, outside of, if not antithetically to, capitalism and its tenets of private property and commodification. While decommodification of housing is the response to the latter, "ownership on control" (Alexander, Ishikawa, and Silverstein 1977), instead of financial ownership, could be the antithesis to the notion of private property.

1.2. LEFEBVRE'S RIGHT TO THE CITY

The issue of housing the socially and economically disadvantaged is by nature enmeshed with the issue of social justice. In the earlier stages, the research had adopted Susan Fainstein's (2010) concept of "the Just City" as its theoretical framework for addressing the issue. In a paper with the same title as her 2010 book, "The Just City," Fainstein (2014) admits that "[she is] willing to embrace reform through existing political-economic processes, rather than viewing greater justice as unattainable under capitalism" (12). But as this research has evolved to take an antithetical position in relation to capitalism, it agrees with Sklair (2017) that "a radical disengagement with capitalist globalization offers the best prospect of escaping from the destructive consequences of class polarization" (256) and its ensuing social and economic injustices.

This radical approach is perhaps best represented in Lefebvre's (1968) concept of "the Right to the City" that has been equally foundational and inspirational for both academic approaches to the issue of social justice and grassroot social movements. According to Marcuse (2014) "For Lefebvre, the Right to the City is a political claim: a cry and a demand for social justice, for social change". In Lefebvre's own words:

The right to the city cannot be conceived of as a simple visiting right or as a return to traditional cities. It can only be formulated as a transformed and renewed right to urban life. (*The Right to the City* in Lefebvre, Kofman, and Lebas 1996, 158)

Lefebvre further elaborates his proposition in *Perspective or Prospective*:

The right to the city manifests itself as a superior form of rights: right to freedom, to individualization, to habitat and to inhabit. The right to oeuvre, to participation and appropriation (clearly distinct from the right to property), are implied in the right to the city. (Lefebvre, Kofman, and Lebas 1996, 173-4)

Lefebvre's call for social justice is a "militant demand for the democratization of control over the collective means of producing urban space" (Brenner 2013, 45). Marcuse (2014), while presenting six different "readings" of the concept, criticizes what he calls "collaborationist reading" which calls for "mild reform" (perhaps those like Fainstein's proposition). He emphasizes "the fact that Lefebvre's call recognized the inevitability of conflict and necessity for struggle [however] is blatantly denied, concealed, and made toothless [by collaborationist readings] behind a facade of good intentions, rationality, and quest for consensus" (8).

As "a deeply spatial understanding of politics" (Purcell 2014, 148) Lefebvre's proposition is all more relevant to the topic of investigation in this research project, i.e., architecture. But, as Marcuse (2014) has cautioned, the spatial nature of the Right to the City should not be mistaken for a narrow reading of Lefebvre's concept as a literal call for designing "the city as a built environment, as physical space" (7) nor should Lefebvre's notion of city be considered "limited in any way to the physical city" (5). This is perhaps best explained by Lefebvre in *Space and Politics*:

The right to the city ... is not a natural right, nor a contractual one. In the most 'positive' of terms it signifies the right of citizens and city dwellers, and of groups they (on the basis of social relations) constitute, to appear on all the networks and circuits of communication, information and exchange. This depends neither upon an urbanistic ideology, *nor upon an architectural intervention* [emphasis added], but upon an essential quality or property of urban space: centrality. ... [T]here is no urban reality without a centre, without a gathering together of all that can be born in space and can be produced in it The right to the city legitimates the refusal to allow oneself to be removed from urban reality by a discriminatory and segregative organization. (Lefebvre, Kofman, and Lebas 1996, 194)

2. CONTEXT

This section outlines the economic and political environment, as well as geographically specific housing policy context where the subjects of investigation,

architects, and architecture, will be studied. Neoliberalism is the political and economic context while Canadian housing policy, particularly in relation to social housing, is the area being introduced as a case study for the geographically specific application of, first, capitalist and, more recently, neoliberal agendas in social housing development.

2.1. NEOLIBERALISM

Brenner (2013) posits that in the context of urban design and planning today “even the most radical designers are seriously constrained by the politico-institutional contexts in which they work” (42-3). These “politico-institutional contexts” have been dominated by neoliberalism since the economically and socially tumultuous years of the 1970s (Purcell 2002).

According to Fainstein (2014) “Neoliberalism’ refers to the doctrine that market processes produce the most efficient allocation of resources, provide incentives that stimulate innovation and economic growth, reward merit, and consequently are conducive to the greatest good of the greatest number.” She further asserts that under this doctrine for “the market to work, state action that distorts prices and interferes with rewards to investors must be minimized; rather the local state needs to offer incentives to investors if it is to compete within the world system of cities.” Fainstein concludes that “under this governing principle, efficiency becomes the single criterion for evaluating public policy, and cost-benefit analysis becomes the tool for its realization” (6).

Both Reagan in the United States and Thatcher in the United Kingdom—followed by other political leaders such as Mulroney in Canada—championed neoliberal thought and policies in the 1980s. Fostered by rapid globalization in the following decades, neoliberalism is today the predominant force in the economic and political arenas worldwide. The overwhelming “neoliberal consensus in favor of free markets” has marginalized the left and labor movements while “[notions] of ‘the public good’... challenged and increasingly replaced by privatization and an emphasis on ‘individual responsibility’” (Dunham-Jones 2014, 155).

Blaming neoliberalism for “declining enfranchisement in the cities”, Purcell (2002) postulates that it has resulted in “a rescaling [of the state apparatus] to sub- and supranational scales, . . . [reorientation of] policy away from redistribution and toward competition, . . . [and] a shift from government to governance” (100). Contextualizing neoliberalism within the field of urban policy and governance Brenner (2013) maintains that “these [politico-institutional contexts] are generally defined by the naturalized imperatives of growth-first, market-oriented urban economic policy and by approaches to

urban governance in which corporate and property-development interests maintain hegemonic control over local land-use regimes” (43).

The previous section identified the theoretical framework of this research project. As a study of the role of architecture and architects in the design and development of social housing within its larger urban context, the preceding provided a brief definition of the “politico-institutional” and economic contexts within which architecture operates. It also helped contextualize the ‘premises’ of this research project—social justice, the public good and decommodification—within the current political environment. The following subsection is a brief study of the geographically specific case study, i.e., housing policy and social housing in Canada.

2.2. HOUSING POLICY IN CANADA: A CASE STUDY

As Walks (2013) has elaborated: “Canada’s cities reveal patterns of urban development, levels of inequality, and rates of growth that follow a middling path between those established in the U.S., UK, and Europe” (155). As such, a study of the Canadian context could provide a balanced—middle of the road—representation of the political, social and economic trends that have been dominating the housing and social policies in the developed countries. In this section, the Canadian housing policy has been primarily evaluated through the role of the Canada Mortgage and Housing Corporation (CMHC) and two main sources: John C. Bacher’s (1993) *Keeping to the Marketplace: The Evolution of Canadian Housing Policy* and John Sewell’s (1994) *Houses and Homes: Housing for Canadians*. Although both books were published in the early 1990s, the Canadian government’s overall social housing policy has not significantly changed since.¹ In fact, by the early 1990s, major shifts towards neoliberal policies had already happened in Canadian housing policy. Two of the main changes were the total abandonment of “Public Housing” development in 1978 (Sewell 1993, 137) and ending federal support for any new “non-profit or non-profit co-op” in 1994 (174).

As “Canada’s national housing agency” (CMHC, “About,” n.d.) CMHC is “a Crown corporation governed by a Board and responsible to Parliament through a Minister” (CMHC, “Management and Governance”, n.d.) “The legislative framework governing CMHC consists primarily of the *Canada Mortgage and Housing Act*, the *National Housing Act* and the *Financial Administration Act*” (CMHC, “Board of Directors and Committees”, n.d.).

The Canadian government’s direction on social housing policy is perhaps best exemplified in an exchange in 1956-57 between Stewart Bates, the head of the CMHC (then called Central Mortgage and

Housing Corporation) and the corporation's board. According to Bacher (1993), the CMHC board "gave Bates [...] a lesson in its philosophy of social housing" when they "informed him that his attitude that public housing should be 'primarily an instrument of social policy to remedy the conditions of the poor who live in bad housing' was *wrong* [emphasis added]" (214). The board made it clear that "the needs of individual tenants should be *secondary*" [emphasis added] to 'economic and urban development considerations.' Public housing would provide only 'a bare minimum of housing for the occupants;' . . . Spartan shelter would make it 'clear' that CMHC was *not* [emphasis added] 'competing with private enterprise.'" (Bacher 1993, 214)²

It may seem unfair to judge the performance of the Canadian government over almost a century through one exchange between the CMHC board and its head less than ten years after the corporation was created. However, both Sewell (1994) and Bacher (1993) have extensively documented how the federal government often in line with its provincial and local counterparts has always protected market housing, home-ownership and the real-estate industry at the expense of social and public housing. What follows is a chronological summary of some 'evidence' provided by Sewell and Bacher that shows the government's bias in favor of the market:

- "The tendency of Canadian cities to regulate urban development primarily to *ensure maximum returns to land speculators* [emphasis added]" rather than addressing the housing crisis, as noted by [Thomas] Adams, pioneer of the Canadian town-planning profession in 1917" (Bacher 1993, 53).
- W. C. Clark's response to the criticism by David Mansur (later the first head of CMHC) "that the benefits of the Dominion Housing Act (DHA) of 1935 were meant to be reserved *for the wealthy* [emphasis added] and that the legislation was *devoid of social purpose*. [emphasis added] . . . he said: all the government wanted was 'to encourage building.'" (Bacher 1993, 92). Not coincidentally, parallel to the government's initiative, Bacher (1993) also points out how during the Great Depression of the 1930s, "the poor were suddenly discovered by unemployed architects, town planners, trade-union leaders, and enlightened segments of the construction industry when they realized that ensuring adequate shelter for low-income families would bring prosperity to their own damaged industry" (37).
- "Centralizing housing authority" through creation of CMHC by the Department of Finance [which] through their control of CMHC's executive board [were] effectively in control [and] responsible for advising the federal Cabinet on housing policy. Social housing would not be an important priority, but merely an incidental frill to deck out a business enterprise in a garb more appropriate to a public agency, achieving the desired appearance of change in the face of a rigid commitment to the *market ethos* [emphasis added]" (Bacher 1993, 180).
- Developing "the Rental Insurance scheme [in the 1950s], which guaranteed the owners of rental housing sufficient income to pay taxes, debt service charges, operating expenses, and repair and replacement costs." However, it resulted in "the construction of *unserved dwellings* [emphasis added], 'cold-water flats' lacking central heating and hot water. [...] Not only was much of the Rental Insurance housing unheated, it was frequently of poor design" (Bacher 1993, 189), so that it would not undermine private market housing.
- Encouragement in the 1950s and 1960s by the federal government of "spartan, severe standards for public housing [...] intended *to avoid competition with entrepreneurs*, [emphasis added] who, it was assumed, would build a better-quality product for those who could afford it" (Bacher 1993, 12).
- "[The] National Housing Act of 1954" that "set the basis for sustained federal assistance to the private mortgage market" and "still forms the basis of federal legislation, reflects the continued thrust of government efforts to prime the pump of the *private market* [emphasis added]" (Bacher 1993, 270).
- The social and economic failure of the Urban Renewal program in the 1960s and early 1970s, despite the fact that it resulted in the increase of Canada's stock of Public Housing from 10,000 in 1964 to 115,000 in 1974 (Sewell 1994, 135).
- "The decision of the federal government in 1972 [...] to exclude from the [capital gains] tax the sale of a personal residence [benefiting] only *owners*, [emphasis added] not tenants, and [...] those whose properties most increase in value" (Sewell 1994, 94).
- The "sudden end of federal land banking in 1978" due to the "opposition from *entrepreneurial housing developers* [emphasis added] and a reduction of city-sponsored and -assisted activity" (Bacher 1993, 11).
- "Support for private rental housing and renters has never been at the forefront of housing policy in Canada" (Sewell 1994, 117).
- Government's investment in home ownership programs "in all likelihood represent a majority of the money spent on housing programs since the Second World War, even though *owners and potential owners*

are not [emphasis added] the Canadians *most in need* [emphasis added] or with the most substantial problems of affordability" (Sewell 1994, 95). In fact, "one big problem [with home ownership programs] is that public housing tenants are poor; they don't have the money to be able to buy and maintain a home" (Sewell 1994, 154).

- Despite the success of non-profit housing in creating "socially successful communities" and over 200,000 affordable housing units in 20 years, the federal government decided in 1994 to end support for any new non-profit housing developments (Sewell, 189).

In summary, Sewell (1994) quotes Farris "that Canada has seen three distinct periods of housing policy: from 1954 to 1963, characterized by stabilization and growth; from 1964 to 1977, a period of equity and affordability; and after 1978, characterized by stagflation and restraint" (14). Although, since publication of Sewell's book, the Canadian economic and political scene has gone through many changes, what has been constant is the shrinkage of government contribution to social or assisted housing programs that started in 1978 and seems to have only intensified under neoliberalism since then.

It should be noted that despite all criticism about the failures of the Canadian government's housing policy over the past hundred years, government initiatives such as the National Housing Act amendments of 1964 and 1973 resulted in significant increase in Public Housing or co-operative units (205,000 of the former by 1978 when the program ended and 200,000 of the latter by 1994). As Bacher (1993) concludes: "Canadian housing policy will continue to fluctuate between the poles of a compassionate, normative community and rapacious striving for economic mastery" (278).³

3. INVESTIGATION

The preceding sections outlined the 'premise' and 'context' of the research project. This section addresses the subject of 'investigation' or research. Although "architectural profession [...], as is commonly known, is responsible for the design of only 2 percent of the annual built production" (Frampton 2005), due to their size and complexity, social housing projects have to almost always be designed by a licenced architect.⁴ This study would examine the role of architects and architecture in the design and development of social housing under neoliberalism and in Canada. As the actual data collection stage of the research—most likely using qualitative methods—has not begun yet, this section provides an overview of architecture from a social and political point of view.

3.1. ARCHITECTURE: A CRITIQUE

Certainly, architecture excludes the world of construction that excludes architects; that is, it excludes those developments that are guided by a profit margin unable or unwilling to pay for professional architectural services. (Deamer 2014, 2)

The above excerpt is from Peggy Deamer's introduction to a collection of writings by architectural scholars on the history of architecture and capitalism. That architecture is in fact in the service of an exclusive group is best reflected in a recent publication by the Royal Institute of British Architects (RIBA), where they stated that today only 6 percent of homes in the United Kingdom are designed by architects (RIBA 2018). But working for this exclusive clientele has also meant being, as Brenner (2013) observed about designers in general, "seriously constrained to the politico-institutional contexts in which they work" (43). Therefore, "[the] architect has always [ended up being] a servant: of a regime, of a society or of an individual sponsor" and "subject to the reason of those in power" (Comerio 1981, 30). Similarly, Sklair (2018) reverberates the concern for architects' servitude to those in power by postulating that "architecture has always been an instrument of control and compliance" (162). Elsewhere, he reiterates: "It has long been recognized that ... architecture has been used to express and reinforce the power of the strong over the weak" (Sklair 2017, 153). The relationship between architecture and the powerful is not a recent phenomenon:

Because building a building costs so much money, construction – and within it, architecture- necessarily works for and within the monetary system. One could say that the history of architecture is the history of capital. (Deamer 2014, 1).

While historically the religious authorities and political power were mostly the source of the "capital" needed for buildings (mostly monumental but also palaces, mansions, villas, and houses of the wealthy), recently architecture "along with every other cultural production (including music, photography, book publishing, the fine arts, and even education), [...] has been increasingly engulfed in and made subservient to the goals of the capitalist economy, more specifically the luring of consumers for the purpose of gaining their money" (Saunders 2005, vii). The subservience of architecture to the capitalist economy has also been reflected in the manner architectural professional practice has evolved.

At the same time that the skyscraper, the symbol of the Chicago School of architecture, gained popularity towards the end of the nineteenth century, it became the target of the labor movement and social activists

of the time who viewed it as the embodiment of mechanization (loss of employment), exploitation of labor, and accumulation of wealth by capitalism (Merwood-Salisbury 2014). Along with their clients' successful attempts to ward off the resistance by the labor movement, "the Chicago construction allowed the contractor and the architect to reposition themselves as managers of the building process, at the expense of the building tradesmen's traditional autonomy" (Merwood-Salisbury 2014, 35). In fact, this repositioning of the architectural profession within the construction industry was not limited to Chicago or the United States. Sklair (2017) points out that as "[the] pattern of architectural production began to change fundamentally in the 19th century [...] architects began to organize themselves professionally" (10).

This alignment of architecture, as a profession, with the values of capitalism and the ensuing detachment from the social issues and concerns of the working class was further exacerbated in the twentieth century. The substantial shortage of housing after the World War II justified further industrialization of building processes and mass production of housing. Thus, the flow of capital towards the building industry in general and housing, in particular, accelerated. Fascinated with the technological advances in mass production, building systems, and materials, architects limited themselves to "the study and application" of such technologies, "only the problems of how [were] relevant; the problems of why were assumed to have been resolved once and for all" (Comerio 1981, 30). Today, "architects working under capitalism ... continue to be seduced by the new technologies and materials it produces and the luxuries they enable" (Schuldenfrei 2005, 91).

Another consequence of the realignment of architectural profession with capitalist values and the ever-growing gulf between architectural practice, on the one hand, and those who are responsible for producing buildings, laborers, and those who use it, the inhabitants, on the other hand, is that profit-making has become the ultimate goal of architecture. Of course, "[architecture] has always been both an art and a business" (Dunham-Jones 2014, 162) and "architectural firms like all businesses in capitalist society, are in business to make profits" (Sklair 2018, 162). In fact, Sklair quotes F. Harder as far back as 1902 when "he had argued that the fine art view of architects was 'all pretty much a delusion . . . they are in reality fully as keen and of as large capacity in the business of money getting as any other constituency in American affairs'." (Harder 1902, 74 in Sklair 2013, 78). However, what seems to be happening under neoliberalism and "in the post-Reagan, postmodern era," is that "the model for architectural creativity [has been] more and more 'big' business"

and architecture has subsequently assumed "the ethic of business as its highest moral imperative" (Sorkin 2005, 28). At the local scale, "instead of challenging the class structure or economic power of the status-quo," architectural practices have been mainly focusing on producing "high design [that] increasingly serves to distinguish its elite patron class from the man in street" (Dunham-Jones 2014, 163).

The question is given the status of architectural practice today, as briefly examined above, and within the 'context' it operates: how or whether architecture as a profession or architects as individuals could contribute to the public good and social justice, when it comes to the issue of social housing. The paper discusses this question in the next and concluding section.

DISCUSSION AND CONCLUSION

Obviously, it would be extremely premature for the paper to offer an answer to the core question of the study or provide any conclusive statements at this early stage of the research. Therefore, in concluding the paper, this section discusses the notions that will hopefully inform the methodological approach and modes of inquiry that could lead to answering the research question.

"So, what is architecture?"

Lefebvre asks the above question in *Space and Politics* (Lefebvre, Kofman, and Lebas 1996, 188). Rejecting it as "art" or "science", "Architecture" Lefebvre believes "cannot be conceived other than as a social practice among others (for example, medicine)" (189). He goes on with the criticism that:

The architect, artist as well as learned man, accepted major fact of the priority of monumentality, the importance of religious or political buildings, over dwelling. . . . He is awkwardly placed between the engineer and the draughtsman; he does not know where he fits between developers, users, financial backers and public authorities. (Lefebvre, Kofman, and Lebas 1996, 190)

In defining architecture as a "social practice" and by emphasizing "*dwelling*", Lefebvre (1996) considers "the architect and architecture" as having "an immediate relationship with dwelling as social act, with construction as a practice." By positioning the architect "between the engineer and draughtsman" he emphasizes the role of the most important medium of architectural production, that of "drawing". Lefebvre then goes on to criticize how architects are deceived by their own drawings, assuming that the sheet of paper they use is "neutral [and corresponding] to the neutral space outside, which receives things, point by point, place by place. As for the 'plan', it does not remain innocently on paper. On the ground, the bulldozer realizes 'plans'." (Lefebvre, Kofman, and Lebas 1996, 191)

Lefebvre (1996) believes that "the architect cannot confine himself to drawing" nor could he "avoid oral consultation with other agents of this production, space" (193). He also rejects the "fragmentation" of space into "abstract spaces" at macro and micro level, which assigns each to the separate disciplines of planning and architecture respectively (194).

PRACTICALITY

Lefebvre's critique of architecture hints at possible alternative means of producing space by architects (for example, by freeing itself from the confines of drawing, engaging other "agents" involved in the production of space and 'defragmentation' of the space itself). But 'pragmatists' raise the question of practicality; not only for realizing Lefebvre's ideals but also for much less challenging tasks, such as provision of proper social housing for the socially and economically disadvantaged. For example, a commonly cited barrier is zoning regulations. As Sewell (1994) points out, these regulatory barriers could range from "precise and prescriptive zoning controls" and "development standards" (64) to "parking requirements" (77), but he also provides examples of flexibility by the municipalities in relaxing such zoning requirements for social housing projects (179). In other words, zoning could also be leverage for local governments to require the real estate market provide some social and affordable housing.

Madden and Marcuse (2016) provide a broader and more informative perspective on regulation. Discussing the "relationship between the tenants and landlords, or between real estate owners and communities", they argue that regulation is a vehicle for providing fairness in a housing market, "a domain of struggle between different, unequal groups." They maintain that absence of regulations could "[shift] the power towards capital and away from residents - while also, not coincidentally, making land more valuable and more amenable to speculation" (47). In fact, as discussed in the 'context' section of this paper, neoliberalism advocates minimizing government intervention in the market. Regulation is the most powerful mechanism at the state's disposal to intervene and rein in the market. So, the call for deregulation, at any level or scale, could indeed be exploited and serve the neoliberal agenda.

Brenner (2013) has also addressed the issue of practicality but from the perspective of the design professionals' lack of "control or influence over investment flows, property ownership structures and political decisions" and answers the question that "isn't it far better to see a good, creative, imaginative design implemented than a bad, derivative, boring one?" (44). His response is that designers' "expertise, creative capacities and labor-power are recurrently

harnessed to mask, manage or soften the socio-spatial contradictions of neoliberal urbanism" and asks the design professionals to:

devise strategies to push back, with their full intellectual capacities, professional influence and political imagination, against the rules, constraints and ideologies imposed by neoliberal, market-oriented systems of urban governance and the forms of sociospatial injustice they produce at all spatial scales. (Brenner 2013, 45)

Brenner's answer could once again raise the question of practicality of such propositions. A convincing response is provided by Lefebvre to those who dismiss his notion of "the right to the city" as utopian or impractical. While admitting that "an orientation of economic growth which would no longer carry within it its 'finality', and no longer aim at (exponential) accumulation for itself, but would instead serve superior 'end' " could result in realization of "the right to the city," he argues that:

"While waiting for something better, one can suppose that the social costs of negation of the right to the city (and of a few others) accepting that we could price them, would be much higher than those of their realization." (Lefebvre, Kofman, and Lebas 1996:7)

OTHER QUESTIONS

The process of literature review for this paper helped refine the core question of the research project. At the same time, several other important and relevant questions emerged. Some of these questions are listed below (the references cited in brackets have directly or indirectly informed the corresponding question):

- What is the role of architectural education in shaping the current status of profession? And vice versa. [Comerio 1981]
- Just as Lefebvre has emphasised, are the working class the only agents capable of achieving "the Right to the City"? [Lefebvre 1996; Marcuse 2014]
- What could be done to scale up the work of architects and designers who are already working with non-profit organizations that provide proper housing for the socially and economically disadvantaged? [Fishman 2018]
- As proven examples of success in the Canadian context, are non-profit and co-operative housing schemes the only alternative and 'realistic' solution to the issue of social housing? [Sewell 1994; Bacher 1993]

While it is expected that the above list grow as the research progresses, these and any future questions will be edited and refined to help either enrich the body of the research (e.g., the scope of the literature review), or inform the methodological approach it adopts (e.g., qualitative research design).

A NOTE ON METHODOLOGY

Being currently in progress and in its formative development stages, the research methodology and design are also in a state of development. The data collection stage of the research would be primarily based on interviews with architects and review of literature mainly published in professional architectural journals. However, architectural education could also be investigated through the same critical lens, where program curricula, studio outlines and course syllabi would be examined. The data analysis stage of the research would then employ discourse analysis—mainly for interviews—in order to identify any common underlying political, social and economic orientations, attitudes and motivations within the discipline. Directed

qualitative content analysis and thematic analysis would also be employed to analyze data collected through both interviews and documents.

ACKNOWLEDGEMENTS

This paper presented a framework for an investigation into the subject of 'social' housing and how it is approached by architects, the design professionals responsible for its various forms, configurations, and styles. As part of a doctoral research project in urban planning, the paper aims to provide an outline and a roadmap. Therefore, while it has been structured as a stand-alone paper, it is indeed a 'live' document that would be further developed as the research progresses.

ENDNOTES

- 1 The current Liberal government has recently initiated a 10-year, \$40-billion program called National Housing Strategy (NHS). However, it is still too early to examine any impacts of the program on housing affordability and particularly social housing as the main topic of this study.
- 2 "Memo, Stewart Bates to Robert Winters, 1 June 1956; letter to Stewart Bates, 12 Feb. 1957, cited in Dennis and Fish, *Programs in Search*, 1293." Cited in Bacher (1993).
- 3 The current Liberal government's National Housing Strategy should also be seen as part of the Canadian government's continuing fluctuation between the two "poles."
- 4 Provincial legislature in Canada requires that a licenced architect, as recognized by the provincial professional bodies, design and supervise the construction of any multi-unit residential building or any building above 3 storeys high or more than 600 square metres.

REFERENCES

- Alexander, Christopher, Murray Silverstein, and Sara Ishikawa. 1977. *A Pattern Language: Towns, Buildings, Construction*. Oxford: Oxford University Press.
- Bacher, John C. 1993. *Keeping to the Marketplace: The Evolution of Canadian Housing Policy*. Montreal: McGill-Queen's Press.
- Brenner, Neil. 2013. "Open City or the Right to the City? Demand for a Democratisation of Urban Space." *TOPOS: The International Review of Landscape Architecture and Urban Design* 85: 42-45.
- CMHC: Canada Mortgage and Housing Corporation (n. d.). Retrieved 10 April 2019, from <https://www.cmhc-schl.gc.ca/en>
- Comerio, Mary C. 1981. "Pruitt Igoe and Other Stories." *Journal of Architectural Education* 34, no. 4 (Summer): 26-31.
- Deamer, Peggy. 2014. "Introduction." In *Architecture and Capitalism: 1845 to the Present*, edited by Peggy Deamer, 1-7. New York: Routledge.
- Dunham-Jones, Ellen. 2014. "Irrational Exuberance: Rem Koolhaas and the 1990s." In *Architecture and Capitalism: 1845 to the present*, edited by Peggy Deamer, 150-171. New York: Routledge.
- Fainstein, Susan S. 2010. *The Just City*. Ithaca: Cornell University Press.
- Fainstein, Susan S. 2014. "The Just City." *International Journal of Urban Sciences* 18, no. 1: 1-18.
- Fishman, Robert. 2018. "The Global Crisis of Affordable Housing: Architecture Versus Neoliberalism." *Architectural Design* 88, no. 4: 22-29.
- Frampton, Kenneth. 2005. "Introduction: The Work of Architecture in the Age of Commodification". In *Commodification and Spectacle in Architecture: A Harvard Design Magazine Reader*, edited by William S. Saunders, ix-xviii. Minneapolis: University of Minnesota Press.
- Harder, J. F. 1902. "Architectural Practice—an Art and a Business." *The Brickbuilder* 11: 74-7.
- Lefebvre, Henri. 1968. *Le droit à la ville*. Vol. 3. Paris: Anthropos.
- Lefebvre, Henri, Eleonore Kofman, and Elizabeth Lebas. 1996. *Writings on cities*. Vol. 63. Oxford: Blackwell.
- Marcuse, Peter, and David Madden. 2016. *In Defense of Housing: The Politics of Crisis*. Verso Books.
- Marcuse, Peter. 2014. "Reading the Right to the City." *City* 18, no. 1: 4-9.
- Marx, K. 1988. (1961). *Economic and Philosophic Manuscripts of 1844*. Translated by Martin Milligan. Amherst, NY: Prometheus Books.

The Microgeographies of Social Justice

- Merwood-Salisbury, Joanna. 2014. "The First Chicago School and the Ideology of the Skyscraper". In *Architecture and Capitalism: 1845 to the Present*, edited by Peggy Deamer, 25-47. New York: Routledge.
- Purcell, Mark. 2002. "Excavating Lefebvre: The Right to the City and its Urban Politics of the Inhabitant." *GeoJournal* 58, no. 2-3: 99-108.
- Purcell, Mark. 2014. "Possible Worlds: Henri Lefebvre and the Right to the City." *Journal of Urban Affairs* 36, no. 1: 141-154.
- Royal Institute of British Architects (RIBA). 2018. "Finding Ways to Design for the Public Good." Accessed June 21, 2018. <https://www.architecture.com/knowledge-and-resources/knowledge-landing-page/finding-ways-to-design-for-the-public-good>.
- Saunders, William. 2005. "Preface." In *Commodification and sSpectacle in Architecture: A Harvard Design Magazine Reader*, edited by William S. Saunders, vii-viii. Minneapolis: University of Minnesota Press.
- Sewell, John. 1994. *Houses and Homes: Housing for Canadians*. Toronto: J. Lorimer.
- Schuldenfrei, Robin. 2005. "Capital dwelling: Industrial Capitalism, Financial Crisis, and the Bauhaus's Haus am Horn". In *Commodification and Spectacle in Architecture: A Harvard Design Magazine Reader*, edited by William S. Saunders, 71-97. Minneapolis: University of Minnesota Press.
- Sklair, Leslie. 2017. *The Icon Project: Architecture, Cities, and Capitalist Globalization*. New York, NY: Oxford University Press.
- Sklair, Leslie. 2018. "The Architecture of Neoliberalism: How Contemporary Architecture Became an Instrument of Control and Compliance." *Planning Perspectives* 33, no. 1: 160-162.
- Sorkin, Michael. 2005. "Brand Aid; or, The Lexus and the Guggenheim (Further Tales of the Notorious B.I.G. ness)". In *Commodification and Spectacle in Architecture: A Harvard Design Magazine Reader*, edited by William S. Saunders, 22-33. Minneapolis: University of Minnesota Press.
- Walks, Alan. 2013. "Mapping the Urban Debtscape: The Geography of Household Debt in Canadian Cities." *Urban Geography* 34, no. 2: 153-187.

MECHANOLOGICAL DYNAMICS IN JACQUES LAFITTE AND GILBERT SIMONDON

Marisabel Marratt
Georgia Institute of Technology

Abstract:

Machines ... extension of man, integrating man himself, extensions of social structures, integrating them. They are at any time identical to us. They are us; they are beautiful like us, and ugly like us. To shape them, to build them, is to build ourselves.¹ (Lafitte 1972, 119)

When Jacques Lafitte, a civil engineer, published his pamphlet *Reflexions sur la Science de Machines* (1932, 1972), he was writing across disciplines, developing a methodology that integrated structural theory, kinematics, and mechanical and civil engineering, with works of art and architecture. Contrary to many writings of the period, his work seeks to define and position the machine as a primary force of integration, rather than as a technological object hell-bent on social alienation. Most importantly, he develops a whole new science of machines, mechanology, which proposes a system of classification that expands on the notion of what constitutes a machine, and is organized according to an energetic and functional evolution; within this system, he situates works of architecture. While Lafitte's words have little purchase in the scientific and cultural milieu of the world between the wars, they acquire new resonance in the postwar period, increasingly dominated by cybernetic theory. They will engage French philosopher of technology Gilbert Simondon, who furthers this exploration of mechanology in his own writings; they will serve to focus his thinking concerning technicity as a "mode of existence" in his secondary thesis entitled *On The Mode of Existence of Technical Objects* (1958). In this recently translated work, Simondon outlines a mode of existence particular to technical objects, by presenting the technical object as a field of operation, thus setting in motion an understanding of the movement of technicity as "ontological force." (Hoel, Van der Tuin 2013, 188)

This paper proposes a "chiasmic" reading of Lafitte and Simondon, to highlight aspects of their little-known work, and to suggest elements in their thinking that may be relevant to contemporary architectural discourse. This machine that both authors seek to define, albeit differently, is explored as both mechanism and organism, an understanding of which may contribute to the current discourse on emergence, as well as offer a new framework for research in architectural history. This paper encapsulates a portion of the preparatory research for the thesis project: "*Gilbert Simondon: Technicity and Technophany in the Chaîne Operatoire*."

Keywords: Simondon, Lafitte, Mechanology, technicity, technical object, machine, technical lineage

Without man, no machine; no man without machine... Just as earth and water form rivers, each continuously conforming to the other, from primitive times, mechanical structures and social structures have composed ... through time, the course of our destiny, have woven the networks of our human life.² (Lafitte 1972, 119)

... a mechanology has existed for a long time, at any rate as a taste, as a tendency and as a poetics of relation between the most perfect industry, or the best equipped science, and Nature at its most natural state, that is to say, the most spontaneous and the most devoid of human contamination ...³ (Simondon 2009, 108)

construct, *mechanology*, as it is developed in Lafitte's *Reflexions sur la Science des Machines* (1932) and then resurfaces in Simondon's *On the Mode of Existence of Technical Objects* (1958). Establishing a lineage for mechanology becomes the pretext of a filmed interview between Simondon and Jean Le Moynes that takes place in August of 1968 at Simondon's country home in Mazeaux-par-Tance. The transcript of this interview, "Entretien sur la Mécanologie," would subsequently be annotated and augmented by Simondon in 1970, archived in the Library and National Archives of Quebec in 1976, and only be published for the first time in 2009 (Simondon 2009, 103-106; Thibault 2017).

This dynamic also involves the milieu in which these works first emerge and become entangled in myriad assumptions and conceptions, regarding the definition and scope of machines, and the ways to model the complex phenomenon, man-machine. Both men, working nearly thirty years apart, reveal similar

INTRODUCTION

The study that follows constructs a dynamic of relations between the work of Jacques Lafitte (1884-1966), architect and civil engineer, and Gilbert Simondon (1924-1989), professor in Psychology and philosopher and researcher of Technics. It traces the evolution of a

desires to capture this phenomenon, in order to give voice to machines' true integration in human culture, yet the nature of this integration transforms with changing philosophical, scientific, and epistemological paradigms. (Simondon 2017; Bontems 2005; Hayward and Thibault 2017; Guffroy and Bontems 2018) The transformation in these fundamental paradigms, shift the nature of the enquiry and fuel the dynamic of this relation.

The connection between Lafitte's mechanology and Simondon's work on the technical object as a mode of existence, and technicity as a human reality and motor of an axiology of individuation was made while researching Simondon's course notes on technics and invention, from the period 1968-1969, in "L'Invention et le Développement des Techniques." (Simondon 2005, 77-226) While the two men never actually met, further investigation revealed that events would place Simondon in a one-degree-removed dialogue with Jacques Lafitte. Simondon's research on the essence of technicity as a movement of concretization from abstract to concrete, of interior organicity progressively structuring an evolving exterior reality, suggest affinities with the phylogenetic lineages explored by Lafitte in his mechanology, or science of machines, proposed thirty years earlier.

This essay draws the contours of this connection, exploring the virtual dialogue that occurs between Lafitte and Simondon, through a series of themed interviews, films, and colloquia, between 1968 and 1976. The events that crystallized around this dialogue offer a unique perspective on a time when scientific, philosophical, intellectual, and cultural interests were diverging along radically different paradigmatic lines, specifically with respect to questions of technology and its implications for the cultural coherence and psycho-sociological health of human society. Both men seek to reverse the perception of technology as a destructive and alienating force, yet their point of departure and framework for structuring such a reversal differ in subtle and fundamental ways. (Bontems 2005) This essay takes a closer look at these inversions as a chiasm, a crossing or transfer that provides a more dynamic understanding of these bodies of work, their cultural reception, and their divergences. The relation between the works of the two men should not be understood as a direct filiation, nor refutation of each other, but as a *technomorphing* of associated contexts, technologies, and scientific paradigms (Guffroy and Bontems 2018; Bontems 2009; Carrozinni 2009).⁴ From Lafitte's conception of mechanology as a theory of the phylogenetic evolution of machines, we are shifted to Simondon's evolving conception of an essential technicity, as an operative enchainment of reticulated and amplified modes of

existence. Thus, this chiasmic mode of analysis and the shift it offers hopes to concretize an understanding of the essential technicity implicit in emergent phenomena and may suggest a different approach to structuring and understanding historical lineages.

1. ASSEMBLING THE PARTS OF THE MECHANISM

1.1. ESTABLISHING THE CHARACTER OF RELATIONS

Tracing the intellectual history of this construct, *mechanology*, across a thirty year gap also means investigating the mechanics of how this conversation crystallized and how the parts that constitute this dynamic entered into resonance with each other. This study traces the development and evolution of *mechanology* in primary and secondary texts, and also explores how this concept became the rallying point around which a series of interviews, films, and conferences were convened and planned between 1968-1976, with Gilbert Simondon as an invited guest, and orchestrated by Jean Le Moyne (1913-1996), a French Canadian intellectual, essayist, and journalist, and John Hart (1923-2002), a computer scientist at the University of Western Ontario and active promoter and translator of the work of Lafitte and Simondon. (Hayward and Thibault 2017; Simondon 2009, 103-106) The shift that occurs during these events, from traditional publications to film and communications media, extends the cultural aims and reach of the intellectual exchange and also changes its nature. (Thibault 2017; Hayward and Thibault 2017) Given this, one may move beyond a simple comparative survey of the theories of the two men to the understanding that the evolution of mechanology as a construct, was actively negotiated "in real time".

The film footage and transcript of the principal interview constitute important evidence for fleshing out the finer points in the convergence and divergence of ideas between Lafitte and Simondon, and also in relation to the cultural ambitions of the Canadian mechanologist movement, spearheaded by Le Moyne and Hart.⁵ These ephemeral transactions often have a tendency to go missing in the historical record; in the context of this study, they are explored as energetic transactions of exchange and transmission, because not only is information being shared, it is also being mediated between the parties, as part of agendas both open and hidden. In the interview itself, the feints and parries between Simondon and Le Moyne, the careful word choices and avoidances, and, as the film stock reveals, the figural intensity of Simondon's gaze and tense posture, which like a coiled spring explodes intermittently in gestural arcs, are indicators that the conversation taking place is not just about paying homage and establishing lineage, as it is about

claiming an intellectual foothold and maintaining one's grasp on the terminology that would structure new paradigms and control future discourse (Hayward and Thibault 2017; Simondon 2009, 103-106).⁶

1.2. THE MECHANISM OF THE MIDDLE

As interviewer-intervener, Le Moyne is the lens through which the lineage is revealed, then traced. Functioning as a third in the relation, his participation is critical and generative and, following the Greek *metaxu* or middle ground, also provides a fertile ground for activating the dynamic of convergence and divergence between the two men. His intervention is meant to validate their assumed common purpose that is to highlight the ever-recurring effort to create a humanist history of machines as a framework for thinking holistically the worlds of machines and men. Le Moyne's lens sharpens the purpose of this exchange: how best to effect this integration in the post-World War II climate, where a proliferation of systems and models for framing reality, to wit cybernetics, information theory, artificial intelligence, and communications technologies, through new tools in mathematics, computerization and communications, risk fragmenting further the project for an integrated human culture (Von Bertalanffy 1969, 19-23; Hayward and Thibault 2017; McLuhan 1994; Wiener 1961; Weiner 1965).⁷

Le Moyne and the Canadian mechanologists focus their effort on the potential of new cultural collaborations emerging across diverse media and specializations. (Hayward and Thibault 2017) A good part of the interview is engaged in brainstorming a film project with Simondon, Le Moyne's project, *La Grande Machine*, which aimed to unfold the genetic history of machines in the visual and temporal medium of film (Thibault 2017). How best to show the continuous evolution of the wheel, for example, within the sequential ruptures of the cinematic medium? This conundrum is debated, pushed, and pulled, as a series of options are discussed, and a resolution is sketched. Then suddenly the discussion breaks. We are on the brink of a philosophical exchange on nominalism, arbitrary natures, and their application to living systems; when the image goes dark, the film winds out, and a gap in the transcript implies a changing of reels. When it restarts, Le Moyne excuses his off-topic musings and shifts from a real-time unfolding of the essence of technicity, back to the script (Simondon 2009, 116-121). The gap, expressed as a literal, physical break in the film sequence, is a temporal reminder of the ghost in the machine and an instance of the chiasmic shift experienced between human and technological realities, the hallmark of Simondon's conception of technicity.

Le Moyne's lens seeks to ignite from this material,

a utopian vision of unity and a project for the future. (Hayward and Thibault 2017) This aligns with the placement of Lafitte along a line of utopian social visionaries, from Fourier to St. Simon, and continuing a critical assessment of history that had been sketched by Henri Bergson and Elie Faure (Vidler 1999). Yet, the resonances that exist between Lafitte and Simondon, eventually subtend frameworks of a radically different kind. Nevertheless, Simondon's work provides Le Moyne a springboard for establishing mechanology as a viable third way, between two ruling paradigms, cybernetics and the image of man as automaton, and media technologies as the extension of the human (Hayward and Thibault 2017; Barthélémy 2012, 104). In developing the machine-as-technical-object, as a concretization simultaneous to its emerging functional schema and associated milieu, Simondon enlarges the zone of extension to include a zone of immersion and augmentation, in the entwining of physical, metaphysical, cognitive, transindividual, and psycho-sociological modes of existence (Simondon 2013; Simondon 2014; Simondon 2017).

For Lafitte, the sole objective of his work on mechanology is to establish a science that studies and explains the differences between machines and their coming to existence (Lafitte 1972, 32). This contrasts with engineering as the art of constructing machines, and the current science, mechanography, which is descriptive, analytic and solely dedicated to knowing machines as objects, according to conventions of representation and the establishment of a taxonomy of extant types. A significant gap exists, between how Le Moyne chooses to read this work, and Simondon's presentation of the mechanological theme. The gap is a distance that exists according to the diverging agendas of the two men. This distance also reflects a controlled restraint on Simondon's part, in his stated project to discover a principle of individuation, and an axiology for the psycho-social, material, aesthetic and technological realities of technical objects, while avoiding the trap of normalizing structures and other such "human contaminations." (Simondon 2009, 108; Simondon 2013). Simondon's studies in technics, ethnology, phenomenology, ethics, and aesthetics show that a larger field of influences is at play in his vision of a mechanology, than is manifest in Lafitte's linear machine phyla. Still, the shifts in emphasis and terminology in the conversation between Le Moyne and Simondon allow one to investigate the energetics of the mechanological dynamic in its evolution.

The gap, as a movement of immersion, entwining, and inversion constitutes a crossing, in the ancient Greek *chiasmus* and exemplified by the x-shaped letter *chi*. The chiasm is identified as a significant figure in

Simondon's work on individuation, the technical object, techno-aesthetics, and the transindividual.⁸ The scope of this essay does not allow expanding on Simondon's conception of the chiasm, nevertheless, it proposes a chiasmic reading of Lafitte and Simondon to suggest that there are mechanisms of crossing that are generative, and which serve to render the dynamics of the evolution of technical lineages. Navigating the chiasm between these works reveals that alongside points of resonance, there exist fundamental shifts in the manner of thinking, structuring, and imagining the man-machine relation, whether as mechanism, as organism, or as some other all-encompassing mode of existence.

2. FLUID DYNAMICS AND ACTS OF DEFINITION

2.1. CAPTURING THE STATUS QUO: THE EXPERIMENTAL METHOD AND TECHNOMORPHING PARADIGMS

Both Lafitte and Simondon choose to define their projects as divergences from the *status quo*. For Lafitte, this *status quo* does not address machines' powerful integration with culture, and so he offers his work as a new discipline and "a social necessity," and that will provide a mode of analysis "long overdue." Its progress runs parallel with human lines of development, "in slow and almost imperceptible transformations," departing from "raw elements of nature" through "primitive mechanisms," then to those structures of a greater organization, he will define as machines. In this progression, we understand a finality, an ultimate convergence of the linear schema of our creations with the most perfect of "organized living bodies", ourselves (Lafitte 1972, 27).

Lafitte enlarges the scope of machines to encompass all man's constructions that exhibit some semblance of organization in form and functioning, including machinery, musical instruments, devices, tools, toys, and architectural constructions (Lafitte, 1972, 28). For both Lafitte and Simondon, the addition of architecture as foundational for an epistemology of machines is significant (Lafitte 1972, i-viii; Simondon 2005, 11-72; Vidler 1999). The classification of machines as mobile, transforming, automatic and anthropomorphic have long existed, however, Lafitte's classifications are ordered according to the complexity of their internal functioning: from passive, to active, to reflexive machines. A single machine may exhibit properties from each group, depending on changes in the internal state of functioning. In the end, the classifications reflect received notions regarding machines as transformers of movement, then transformers of energy, and finally, in their reflexive mode, as adapting to feedback (Lafitte 1972, 50-73).

Lafitte's mechanology as normative science studies the differences between singular examples, and the causes affecting their transformation. This bottom-up approach is dedicated to capturing the phenomenal existence of machines, not a final idealized form. The classification orders the differences observed in form, structure, functioning, and in their general organization; this allows an actual mapping of the genesis of each type and also allows Lafitte to draw a parallel between human development and machine's functioning and organization (Lafitte 1972, 34).

Simondon will make use of Lafitte's classifications, with some modification, during his course development in 1968-1969 (Simondon 2005; Bontems 2017). Yet Simondon's interest lies in proposing the technical object as a technical ensemble of diverse modes of existence; it is neither of man nor of technics, but of nature in man and nature in technics (Barthélémy 2009, 82). He is a "philosopher of concrete particulars," where a sensibility for material specificity is inversely matched by the expansive and reticulated movement of the transindividual in his third term, the network (Hayward and Thibault 2017, 2; Simondon 2009, 129; Barthélémy 2009, 79-80). Both abstract and concrete, his work reflects divergent influences,⁹ and is grounded in his research on individuation and the technicity of the technical object, which he develops in his primary and complementary doctoral thesis (Simondon 2013; Simondon 1958). The latter work introduces the genesis and existence of the technical object and its associated milieu, according to notions of an "essential technicity." Simondon's study of technicity is anchored in works of engineering, architecture, art, industrial design, and simple tools and embeds the topologies, materials, and gestures of their becoming. He privileges these technical objects as modes of existence and as introducing a reality that manifests a specific form of participation, a technical mentality that structures its own axiology, according to the conditions of existence (Simondon 2009, "Technical Mentality").

The technical object is very interesting in the sense that it causes a third term to appear, which is a term of physical reality because the technical object is made from metal, wood, etc.: it comes from nature. Moreover, thus this technical object does not have a violent relation with nature, but when it intervenes between man and nature, it intervenes as a third, as a kind of *metaxu*, organizing the relation and allowing human society to be, with respect to nature, in a relation that is at once extremely concrete but much more refined ... more intelligent and interwoven at a greater order of magnitude than if man were to intervene by himself; man by himself causes too much devastation ... So I feel the necessity of this third term, which is the network, at the same time nature and man, not just technics: it is technics in one sense, but a technics that is at once nature and man.¹⁰ (Simondon 2009, 129)

If one follows Lafitte, reflexive systems adapting to feedback are a higher-order complex machine approaching the living, but for Simondon they do not encompass the living as an open ensemble of operations, in continuous entanglement with its auto-generation, its psycho-social technicity. Reflexive systems do not allow for the evolution of the essential lines of existence (Simondon 2009). Simondon's project is to uncover the contours of this axiology and to shine a light on the "already always existing" through different phases of individuation. This axiology, as a structuring, is at once abstract and specific, capturing the *haecceity* of distinct modes of existence, while deriving a principle of individuation from this very coming to existence; in this light, he models his thoughts on the technical object (Simondon 2013, 30).

2.2. THE MICRO-MOVEMENT OF DIVERGENCE

Of the distinct resonances that exist between the two men, not the least is the importance of the evolution of technical lineages and the immersion-inversion of technological and aesthetic realities. The differences that exist are a function of each man's time; these do not play out as a dichotomy, but rather as micro-movements in a diverging field. Lafitte's attempt at capturing the transforming *status quo* in a revised system of classification, however broad in its scope and supple in its functioning, still presents like a taxonomy of marvelous things. Contrary to the growing disillusionment with the industrial age that pervades this period (Hayward and Thibault 2017; Lafitte 1972, i-viii), Lafitte's description of skyscrapers, engineered structures, and industrial machines is suffused with a sense of wonder for the energy and scale that are, to him, the sublime apotheosis of a modern age (Lafitte 1972, 34). Whereas Simondon, equally in awe of the marvels of his time, such as the launching of the Sputnik into orbit in 1957, is nonetheless aware that *his* time is experiencing a radical paradigm shift, which is as much technical as it is transformational of man's perception of his position in this world. The age of information has rendered any system based on a simple classification of things, however fluid in their interactions, virtually lifeless (N. Simondon 2014).

Undergirding these differences, are fundamental transformations in the notion of progress. In following a developmental sequence, Lafitte follows a linear and classically teleological movement of perfecting. This notion of a final perfection pervades, as when he refers to a "certain modern group of architects," for whom form and function necessarily are a unity (Lafitte 1972, 105). Yet, as he lays out his plan, Lafitte will distinguish this unity from an "organic perfecting," which become the micro-adjustments or adaptations

taking place in the internal mechanisms of his machines, culminating in the responsive mechanisms of his reflexive machines (Lafitte 1972, 34). His linear sequences transform to form branching structures that express the micro-adjustments taking place in internal mechanisms. The branching establishes the series, which leads to the genesis of types. As precursors to his thinking, Lafitte acknowledges Franz Reuleaux (1829-1905), Felix Cardellach (1875-1919), and Charles Babbage (1791 -1871), noting in this work that the progressive perfecting of overall organization parallels a structural perfecting (Lafitte 1972, 105).

Simondon will complexify this forward march of progress, by rendering it circular, with the capacity to act upon itself, and by proposing "different modalities of the notion of progress" in suggesting that progress itself has a history (Simondon 2017, 129). Essential to this notion of progress is the acceptance of the technical object as an "ensemble of elements"; each at different times undergoes refinement of conception and craft. Progress is thus first experienced by the prehistoric tool bearer, then the artisan, then by *no one*, as technical ensembles become autonomous and self-sustaining, provoking individuals' anxiety and leading to social alienation. The essence of Simondon's idea of progress is the relation with this individual, who is an ensemble of technical and social modalities; associating progress with mathematics' possession of nature is symptomatic of a grave cultural problem. "The alienation of man in relation to the machine does not only have a socio-economic sense; it also has a physio-psychological sense..." (Simondon 2017, 133)

From the perfecting of an object named machine, we shift to the molecular and augmented notion of individuals and technical objects as psycho-social and technical existence. Simondon's notion of progress of any technological system requires the inverse of perfecting; a technical object prolongs its existence and innovates only insofar as it undergoes a continuous im-perfecting. Im-perfecting involves, a dephasing or *décalage*, of rhythmic alternation, thus effecting a dynamic that is both disrupted and continuous. Each phase undergoes its own temporal transformations simultaneously redefining the trajectory of the ensemble (Simondon 2017, 176). The technical object exists at odds, divided unto itself, and will find in this dephasing the essence of its transformation and evolution (Barthélémy 2009, 80). The idea of perfection is problematic because it is static; it also concerns Simondon because it results in a cultural hysteria that is too quick to establish the obsolescence of objects; this is evidence of a culture that no longer recognizes that the essence of the object lies in its "essential lines" (*lignes essentielles*),

its temporal existence. This surplus-deemed-obsolescence re-establishes the magical unity that precedes such polarizations as culture and technology (Simondon 2009, 109; Simondon 2017, 191-211).

Following this, another fundamental difference will define the point of departure and the resulting epistemologies of the two men. While Lafitte expands the scope of man-made machines as object of enquiry, Simondon is intent on reconfiguring the humanist paradigm as non-centripetal (Simondon 2009, 104). Lafitte's machines parallel the progression and development of man's consciousness: first, a consciousness of form (where a sense of movement is implied), then the forces involved, and then the variations in the forces involved, resulting in his passive, active, and reflexive categories of machines (Lafitte 1972, 85). In Simondon's case, the technical object augments the breadth and depth of the field of humanity, with technicity as the third component in the relation, between man and technics, and technics and nature. Simondon's inversion consists in abandoning this anthropometric model and its linear schema of historical progress, which too easily forgets that variations exist in the field of evolution of technics, of culture, of habit, and of inhabiting. A linear schema for technical modes of existence is impossible in this light. For Simondon, evolution should be schematized as a proliferation, a fanning out. In this fanning out in all directions and according to diverse temporalities, Simondon envisions a radiating and reticulated expanse, where the existence in question is no longer composed of one, and certainly no longer a function solely of man, but of an internal resonance and reciprocity proper to the mode of existence of the relation nature | technics | man (Simondon 2009, 109).

2.3. FRAMING MACHINES | MACHINING FRAMEWORKS: DISTRIBUTIONS AND CLASSIFICATIONS

In his book, Lafitte writes across disciplines. The frontispiece reveals his work as the fruit of a collaboration, when he invokes his progenitors and crisscrosses the movement of their lives. Calling forth the architect-engineer, the artist, the stonemason, the metalsmith, and the sculptor from his lineage, Lafitte provides a personal reflection on the complex dynamic that engenders human realities and the mechanisms with which we forge our identities (Lafitte 1972).

The entwining of machines and men is a potent subject throughout this period, as a survey of the works of cultural criticism, ethnology, sociology, literature, and history would attest. The offerings are varied and heterogeneous; and reveal that subtle polarizations are taking place during Lafitte's time. The idea of progress

and the myth of modernity is an invigorating tonic for some, while others are increasingly threatened by the heightening industrialization, standardization, and the reformulation of work-as-labor. This perceived mechanization of the world, *machinisme*, variously understood as Taylorism, standardization, homogenization, and the systemized organization of parts, provokes much ambivalence, if not hostility, in Lafitte's day, but by the time Simondon enters the frame, the proliferation of post-World War II systems "solutions" as synonymous with human progress will become even more problematic. These are perceived as mounting an assault on social coherence and the preservation of human value(s). Two tendencies emerge from these conditions; a *technophobia* that refuses the idea that machines, *by any definition*, could be aligned with human nature and a *technophilia*, which becomes the siren song for further abstraction to an entire generation.

Lafitte avoids polarizations of this kind, and seeks a middle ground that would enable exploration of the problem of existence of machines. The challenge is the development of a science capable of describing what happens, rather than describing the outcome of an analysis of preformed facts or objects. By definition, this means that the science of machines as mechanology must constitute itself as "a field" even as an exact definition of what constitutes its boundaries must always elude one's grasp (Lafitte 1973, 32). The process of definition is the first step in the measuring and the perfecting of this knowledge. Lafitte determines his expanded system of description and classification will highlight how machines' existence, *as phenomena*, are distributed and characterized in their functioning. From the founding of this middle ground as both empirical and normative science he hopes to perfect his understanding of machines as a primordial force of integration between nature and humanity. Lafitte's desire to reframe the perception of machines is nonetheless anchored in classical science. Science proceeds by the observation, collection, and measuring of distinct phenomena, and their repetition and variation. To understand the principles and causes of these phenomena, they must first be described, then normalized; i.e., categorized and classified. Only then can these differences or variations be discerned and understood.

Yet Lafitte concedes that establishing a definition is problematic, because to define means automatically to assume an attained perfection, thereby circumscribing and limiting the potential of a machine configuration. This framing assumes that the assemblage exists as separate and autonomous from everything that surrounds it, and this is a fallacy, for nothing defines machines better than a living being.

"Any definition that one might propose is nothing more than an approximation ... and dangerous because it tends to crystallize in immutable form what is essentially a phenomenal, moving reality. Nothing defines machines better than the living."¹¹ (Lafitte 1973, 29). Lafitte's system of framing is thus informed by the isomorphic relation between progressions of natural and physiological phenomena and emerging and developing machines; all are seen to follow the same natural order. However, rather than stop at a bio-mimetics and imitation of perfected forms, Lafitte expands his field of reference to include the "vaster science" of organology, and the knowledge of a functioning that subtends all mechanisms, especially but not exclusively those of the living (Lafitte 1973, iv).

Lafitte is not the first to establish a homology between the functioning of machines and the living, but it is striking to follow the implications of this passage for a study of technical lineages and acts of framing. For any form of empirical knowledge to progressively "perfect itself" via the experimental method, the implication is that "All is machine », even the frame, and therefore a "living" system must be elastic and open and not fixed in its constraints. Like some kind of open cellular structure, it should be useful and appropriate, so long as it serves the phenomenon it seeks to define by this framing. The machine, the phenomenon of emergence, and the system of description and classification engender each other.¹² Following Lafitte, the system of classification as "*machine opératrice*" and "*machine motrice*," becomes itself machine. The nature of this dynamic of movement will be Simondon's to explore, more specifically with his conception of transduction.¹³

2.4. MACHINE INTERVENTIONS | IMMERSION MACHINES

If all is machine then what of man? The moment arrives in his analysis where the rules of the road established by Lafitte in his archly humanist endeavor lead him to the edge of a precipice from which, by his own admission, he does not dispose of the tools to leap (Lafitte 1973, 62). The underlying implication of this question: if this perfectioning is not the fruit of man's intervention, and follows from an internal progressive ordering, then what is the relation of human intervention to the differentiation and variation of these creations?

The deeply philosophical nature of this question is also a problematic one, as Lafitte considers the means of mapping the characteristics of his study as a science. He troubles the differences and affordances of distribution and classification to make sense of the capture of continuous phenomena. A genealogical distribution in machines is continuous and reproduces

the order followed by man in creating it. The distribution is as permanent as the temporal order it follows, and, if observed in its proper sequence, allows identification and marking of invariants over time. On the other hand, a classification is discontinuous, arbitrary, and always in formation because its progress is marked by greater precision and finer tuning (according to progressively granular distributions). The troubling has to do with whether this approximation, in however incremental a fashion, will ever approach the real. The question revives the concerns of the ancient Greeks and, in particular, Zeno's paradoxes. Yet, Lafitte writes in an age when advances in mathematics, the physical and the natural sciences hold some promise of resolving this conundrum.¹⁴ In the end, Lafitte comes to terms with the impossibility of resolving this essential paradox; it seems not possible, because what he seeks to capture (technomorphing) is continuous and, as such, not actually divisible, while classification, which is arbitrary, is by definition and nature nothing other than discontinuity and division (Lafitte 1973, 64).

Lafitte acknowledges he lacks the proper tools, but he does not admit defeat. Man must continue these "stoppages" to increasing levels of granularity, in order to arrive at a point of immersion, to situate oneself, in the ensemble of the distribution. "... our spirit, in order to situate itself in the complex ensemble of this distribution, will deploy stoppages that will serve as moments of rest and points of reference."¹⁵ (Lafitte 1973, 62). The emphasis here is placed, not on the reference points, but on stoppages. These time gaps are experienced as immersion, and crystallize the figures that are the "partial truth" of a continuous reality. It is these discrete and partial moments, "the discontinuous figuration of an essentially continuous distribution" that are our artificial constructs, where generation and invention are fused. "At each instant, it cannot be other than a language, an image, ceaselessly perfecting themselves, of a reality that it will only ever be able to express partially."¹⁶ (Lafitte 1973, 64). Lafitte draws the line in the sand, frankly acknowledging that he leaves the problem for a different methodology to tackle. This is less the result of an absence of technical means than of a narrow perceptual bandwidth. Simondon is left to flesh-out the stoppages left by Lafitte and transform the mechanological dynamic into operative chains of reticular modes of existence, as a network that reveals an internal structure of resonances and reflects a human need.

There would not be a network if there did not exist, a certain natural structure, on the one hand, a certain human need on the other, and then the invention of a harmonious relation between this nature, and human needs. The network is the encounter of technical possibility and a natural existence.¹⁷ (Simondon 2009, 126)

This encounter does not function according to the laws of linear causality, or of a system of distribution and classification perpetually being reframed; it is as a self-structuring alternation of energetic transfer, corporeal perception and technics. "If one wants to understand a being completely, one must study it by considering it in its entelechy and not in its inactivity or its static state." (Simondon 2009 "Technical Mentality," 19). His collected works will place their focus on a lineage of techniques and their essential schemas (*lignes essentielles*), rather than a history of objects defined as machines. This necessarily engages an exploration of a field of relations as *technicity*, and expands the field of perception as the manifestation of a proliferating technical mentality. "*Elle offre aussi un éventail extrêmement large de perception, et même de perception magnifiée, dans le domaine des techniques...*" (Simondon 2009, 126). By presenting the genesis of the technical object as a field of operation, Simondon diverges from the nineteenth century model of scientific knowledge, in favor of a modern-day version of alchemical science. He nurtures the emerging technical mentality, an-axiology-in-development, which in its "incomplete genesis" is necessarily messy (Simondon 2009 "Technical Mentality," 17), but which sets in movement an understanding of technicity as an "ontological force." (Hoel and Van der Tuin 2013, 188)

3. THE DYNAMIC OF THE EXCHANGE

3.1. CANADIAN TRANSPOSITIONS: THE HISTORIOGRAPHICAL MOVEMENT

The general contours of this evolving mechanological dynamic now drawn, warrant returning to the conditions that lead to the virtual meeting between Lafitte and Simondon.

Simondon's work exerts a strong influence on a group of Canadian academics and intellectuals in the late 1960s and 1970s. Alongside Le Moyne, John Hart is intent on launching an international dialogue on mechanology, as a means to further his own research interests in computers, automata, and prosthetics.¹⁸ (Hayward and Thibault 2013, Hayward and Thibault 2017, Thibault 2017) Simondon's thesis works precede his discussions with Le Moyne by a decade, yet it is with the ideas developed in the complementary thesis that Le Moyne is specifically concerned. Le Moyne's interests are more analogue, polemical, and anchored in the desire to shape the cultural discourse, through films, exhibitions, and through highlighting the work of key intellectual figures. Both men seek to reinvigorate the perceived mid-twentieth century stalemate between culture and technology, and aim to highlight the profound human engagement with machines, by privileging the poetics of this engagement, the

pragmatic necessity of this relation and the logic of its movement (Hayward and Thibault 2017; Thibault 2017).

Hart and Le Moyne anchor a network of collaborators that explore diverse forms of "artistic and intellectual inquiry into "the machine" as an "object of knowledge." (Hayward and Thibault 2017, 450). They wish to further Lafitte's project by "manifesting mechanology," in myriad and heterogeneous media, such as in documentary films, essays, broadcasts, and in designing computer interfaces (Simondon 2009, 104; Hayward and Thibault 2017; Thibault 2017). Yet, the mechanology "movement" never gains much traction, in part out of lack of funding and internal coherence of actions, and also because it is stuck at the crossing between two dominant intellectual paradigms of the time: Norbert Wiener's cybernetics and Marshall McLuhan's ideas on communication and media, emerging from the Toronto School of Communication (Hayward and Thibault 2017; Thibault 2017). These paradigms do not address the cultural aspirations of Hart and Le Moyne, thus their insistence on a third approach, which would encompass the frameworks of science and the humanities. Alongside translations of key texts and filmed interviews with important figures, they organize two symposia on mechanology at the Canadian Cultural Center in Paris in 1971 and 1976, in which many, including Simondon, are important participants (Hayward and Thibault 2017; Simondon 2009, 104; Carrozzini 2009; Guffroy and Bontems 2018).

3.2. THE DYNAMICS OF THE TRANSMISSION

The brief sketch on the history of the mechanology movement in Canada sheds light on the underlying dynamics of the meeting between Simondon and Lafitte. As an actual meeting, the conversation never occurred; instead, the two men met virtually in the context of a series of programmed events, involving Simondon, Hart, and LeMoyne during 1968-1976, during which the conversation around mechanology became progressively more diffuse (Thibault 2017; Bontems, 2018). The transcript of the 1968 interview was reviewed and annotated by Simondon in 1970, and finally submitted to the Library of the National Archive of Quebec in 1976. First published in 2009, "Entretien sur la Mecnologie" then found a second printing in *Sur la Technique* (2014), as part of a compilation of Simondon's writings. It has yet to be translated into English. The transcript and reels of film footage, deposited in the Library and National Archives of Quebec in 1976, were only rediscovered in 2007. Subsequent digital copies were made and disseminated, and a low-resolution copy of each reel of the film stock was made available for viewing on the internet.¹⁹ (Simondon 2009, 103-106)

The archival material from the interview intrigues at many levels: for what is discussed, for how it is staged and then for Simondon's performance as he acts out his energetic schemas with props and diagrams, in a quasi-pantomime of his abstract-concrete approach. The emphasis on the performative aspect of the interview is further underlined by the fact that, although this takes place in August at his country home, Simondon is nonetheless fully suited up and in a lab coat of sorts, at once projecting the image of the messianic technologist and the pithy philosopher-intellectual (Thibault 2017). The camera, positioned as if from the interviewer's point of view, zooms in several times on Simondon's face, as if to capture and pin him down like an entomological specimen in a taxonomy. Vincent Bontems notes the striking stillness and fixity of his gaze one moment, only to be followed by gestural outbursts, while he makes his argument tangible (Simondon 2009, 104). The stoppages of the film stock show the arc of this energetic movement in staccato; they describe a dynamic that is intense, in a continuous alternation between movement and rest, and refusing to be captured. The same may be said about the conversation.

Underlining the dynamics of this exchange is Simondon's apparent refusal to be inserted in a lineage or into the mechanism of others' agenda. He claims only a recent discovery of Lafitte's work and then begs little familiarity with more central cultural references, like Franz Reuleaux and Gaston Bachelard. Simondon studiously avoids being pinned down, except for when he wants to be, which suggests a subtle strategy for directing the course of the conversation. He readily discusses the influence of the cybernetics of Norbert Wiener (1894-1964), the anthropology of André Leroi-Gourhan (1911-1986), and even reflects that a true mechanology exists in the imaginative science fiction of Jules Verne (Simondon 2009, 108). While Simondon may simply be attempting to "stay on message," the reticence to reveal the sources that inform his thinking indeed presents difficulties in tracing his own lineage (Simondon 2009, 103-106).

With these interpersonal dynamics sketched, the transcript of the interview shows that there is also more at play than the coy reluctance to reveal one's hand. Important words, as concretizations, are being negotiated. Le Moyne's *rapprochement* of Simondon and Lafitte consists in conflating such terms as *technical object* and *technicity* with *machine* and *machinisme* (Hayward and Thibault 2017; Simondon 2009). Simondon politely resists using terms like *machine*, and *rationalité* in the conversation, because these belong to paradigms that can no longer speak to the present reality. His studied

avoidance of Le Moyne's liberal and searching use of such words as *machine*, *machinisme*, *rationalisme*, and *phénoménologie des éléments*, in preference for his own precise vocabulary of terms, such as *objet technique*, *essence technique*, *lignes essentielles*, *psychosociologie*, *concrétude* and *milieu*, indicate he has in mind a very different constellation of terms for exploring individuation, the transindividual technical object and technicity. Rather than shield his cards, Simondon performs the inverse: he fully plays his hand.

CONCLUSION

In orchestrating this moment of convergence, the Canadian mechanologists had hoped to seed their own movement and ensure its longevity, and *inevitability*, by establishing a continuity of lineage between the works of Jacques Lafitte and Gilbert Simondon. Their hope was to navigate the shifting paradigms of their time, on the bedrock of a historicity of machines. The argument may be made that this is the mechanism with which all histories are set in motion, but, in this case, this was not to be, for reasons that go well beyond the parameters of these series of conversations (Hayward and Thibault 2017; Thibault 2017).

The concept of technical lineages was proposed by Simondon and Lafitte to better understand the "historical evolution of technical objects" (Bontems 2009, 3). From a vision of linearity and continuity, we are shifted to a vision of a history that is non-linear, fanning-out and rhythmic, and which finds its coherence in the reticulated relations and layerings of technical ensembles (Simondon 2009, 126). As this study has hoped to show, the mechanological dynamic that is set in motion by the virtual dialogue between Lafitte and Simondon, reveals a structuring that inverts the "direct line of descent" of a genealogical lineage, for a multi-dimensional, multi-temporal, analogical network of relations.

ENDNOTES

- 1 Author's translation. *"Les machines? Prolongement de l'homme, s'intégrant à lui-même, prolongement des structures sociales et s'intégrant à elles, elles sont, dans tous les temps, identiques à nous-mêmes. Elles sont nous ; elles sont, comme nous, belles, et laides, comme nous. »*
- 2 Author's translation. *"Sans homme, pas de machine; pas d'homme sans machine ... Comme la terre et l'eau forment les fleuves, l'une à l'autre toujours se conformant, dès les temps primitifs, les structures mécaniques et les structures sociales ont composé, sans cesse, à travers les âges, le cours de nos destins, ont tissé les réseaux de notre vie humaine. »*
- 3 Author's translation. *"...il y a longtemps qu'une mécanique existe, tout au moins comme gout, comme tendance et comme poésie du rapport entre l'industrie la plus parfaite, ou la science la mieux équipée, et une nature à l'état le plus naturel, c'est-à-dire la plus prime-sautier et le plus absent des souillures humaines ... »*
- 4 Lafitte's system finds analogy with nineteenth-century biological sciences, while Simondon's theories reference more contemporaneous developments in science, technology, and the social sciences, from the Theory of Information, cybernetics, and the Laws of Thermodynamics, to psychology, sociology, and ethnology.
- 5 The research of Mark Hayward and Ghislain Thibault on the history of the mechanology movement in Canada facilitated an understanding of the dynamic between the Canadians and their intellectual sources, as well as the political transformations occurring in Canada during this time.
- 6 The filmed interview may be accessed in its three reels on YouTube according to the following links. Last accessed 12/12/20
Reel 1/3 <https://youtu.be/VLkj8U5PoQ>
Reel 2/3 <https://youtu.be/HRqy9vttW-E>
Reel 3/3 <https://youtu.be/kCBWTHjKvBU>
- 7 If one follows Norbert Wiener's work from his first introduction of cybernetics (1948, 1961) through to his reflections published posthumously (1965), one notes moments of questioning, which some have construed as remorse.
- 8 A short list of those scholars who have shown interest in the chiasm are: Jean-Hugues Barthélémy, Muriel Combes, and Ludovic Duhem. This influence of the chiasm may draw in part from Simondon's familiarity with the final work of Maurice Merleau-Ponty (1908-1961) (Merleau-Ponty 1968), an important mentor, and to whose memory Simondon dedicates *On the Mode of Existence of Technical Objects* (1958). However, the exact nature of this chiasmic crossing for Simondon will also draw from his studies in anthropology, religion, aesthetics, the medieval alchemical sciences, and the physics of the pre-Socratic philosophers.
- 9 His influences range from studies in ethnology and anthropology with Marcel Mauss, and more importantly, André Leroi-Gourhan, studies in phenomenology, particularly the work of his mentor Maurice Merleau-Ponty, the Psychology and Phenomenology of Henri Bergson, the History of Science and Technology through another mentor Georges Canguilhem, and Norbert Wiener's cybernetics, to name just a few of the principal ones.
- 10 Authors translation. *« L'objet technique est très intéressant dans la mesure où il fait apparaître un troisième terme, qui est un terme de réalité physique, car l'objet technique, c'est fait avec du métal, du bois, etc. : il vient de la nature. Et cet objet technique n'a donc pas de rapport de violence avec la nature mais, quand il intervient comme intermédiaire entre l'homme et la nature, il intervient comme un troisième, comme une espèce de metaxu organisant la relation et permettant à la société humaine d'être, par rapport à la nature, dans un rapport à la fois extrêmement concret mais beaucoup plus raffiné et beaucoup moins dangereux pour l'homme ... Mais moins dangereux aussi pour la nature, moins destructive, plus intelligent et tissé sur une plus grande échelle que si l'homme intervenait directement tout seul : l'homme tout seul fait beaucoup de ravages ... Donc, je pense qu'il faut le troisième terme, qui est le réseau, à la fois nature et homme, et pas seulement technique ; il est technique en un sens, mais c'est une technique qui est à la fois nature et homme. C'est un troisième terme ; c'est un terme de médiation, un moyen terme comme diraient les Grecs, ce qu'il faut trouver pour organiser la relation. ».*
- 11 Author's translation. *« Toute définition qui s'en pourra proposer ne sera qu'une approximation ... et dangereuse parce qu'elle tend à cristalliser dans une forme immuable l'expression de phénomènes essentiellement mouvantes. On ne définit pas mieux la machine que l'être vivant. »*
- 12 In this discussion of frames and technology, continuities and discontinuities, one must acknowledge Martin Heidegger's essay, "The Question Concerning Technology" (1957), in which he discusses the essence of technology as an enframing, *gestell*, of man's being-in-the-world. The enframing serves as a gathering together, but it also presents the challenge that the enframing also masks the process of its "bringing-forth" into the world. An exploration of this essay relative to Simondon's work is entirely pertinent, as well as for exploring the conundrum Lafitte encounters with his system.
- 13 For Simondon, the term transduction avoids the compartmentalization of knowledge and processes that result in alienation and arbitrary divisions between domains, "it expresses individuation and allows it to be thought ... it applies to ontogenesis and is ontogenesis itself." (Combes 2013, 8) Transduction allows for expression of the process of individuation, as well as the possibility of thinking it. This process bears witness not only to its own becoming, but also to the constellation of relations that emerge along with it, in other words, milieu.
- 14 Logicians and mathematicians Herman Weyl and Bertrand Russell sought to refute assumptions proposed by Zeno, relative to the divisibility of space, whereas Henri Bergson would propose in *Matter and Memory* (2014) that while space may be divisible, duration – motion is not.
- 15 Author's translation. *"À défaut d'une représentation de forme mathématique, notre esprit, pour se retrouver dans l'ensemble complexe de cette distribution, y pratiquera des coupures qui lui servent de repos et de points de repère. »*

16 Author's translation. « Mais par le fait même qu'elle distingue des groups là où il n'en existe réellement pas, par le fait qu'elle donne la figuration discontinue d'une distribution essentiellement continue, elle ne pourra jamais atteindre la vérité par elle-même Elle n'est et ne peut être, dans chaque instant, qu'un langage, qu'une image, sans cesse perfectible, d'une réalité qu'elle n'exprimera jamais en son entier. »

17 Author's translation. « Il n'y aurait pas de réseau s'il n'y avait pas une certaine structure naturelle d'une part, un certain besoin humain d'autre part, ensuite l'invention d'une relation harmonieuse entre cette nature, et ce besoin humain. Le réseau, c'est la rencontre de la possibilité technique et de l'existence naturelle. »

18 Hart spearheads and produces an earlier partial translation of Simondon's *On the Mode Of Existence of Technical Objects*. Hart also publishes, in a limited run with his Mechanology Press, a translation of Lafitte's work as *Reflections on the Science of Machines* (1969). An extant copy of this translation was unobtainable, leading to the author's own translations.

19 Refer to note 6.

REFERENCES:

Barthélémy, Jean-Hugues. 2012. « Sur l'Architectonique de *Du Mode d'Existence des Objets Techniques* ». In *Cahiers Simondon Numero 4*, edited by Jean-Hugues Barthélémy, 97-135. Paris: L'Harmattan.

Barthélémy, Jean-Hugues. 2009. «Du Mort Qui Saisit le Vif. Sur l'Actualité de l'Ontologie Simondienne». In *Cahiers Simondon Numero 1*, edited by Jean-Hugues Barthélémy, 77-90. Paris: L'Harmattan.

Bergson, Henri. 2014. *Matter and Memory*. Translated by Nancy Margaret Paul and W. Scott Palmer. Kent, England: Solis Press.

Bertalanffy von, Ludwig. 1969. *General System Theory, Foundations, Development, Applications*. New York: George Braziller.

Bontems, Vincent. 2009. "Gilbert Simondon's Genetic « Mechanology » and the Understanding of Laws of Technical Evolution." *Techné*, Vol. 13, No. 1 (Winter): 1-12.

Carrozzini, Giovanni. 2009. "Gilbert Simondon et Jacques Lafitte: Les Deux Discours de la « Culture Technique » ." In *Cahiers Simondon I*, edited by Jean-Hugues Barthélémy, 25-45. Paris: L'Harmattan.

Combes, Muriel. 2013. *Gilbert Simondon and the Philosophy of the Transindividual*. Translated by Thomas LaMarre. Cambridge: MIT Press.

Faure, Elie. 1937. *History of Art: The Spirit of the Forms* (Deluxe Edition). Translated by Walter Pach. Garden City: Zone Books.

Guffroy, Yohann and Vincent Bontems. 2018. "La Mécanologie: Une Lignée Technologique Francophone?" *Artefact*, 8, 2018 : 255-280.

Hayward, Mark and Ghislain Thibault. 2017. "Understanding Machines: A History of Canadian Mechanology." *Canadian Journal of Communication*, Vol 42: 449-466.

Hayward, Mark and Ghislain Thibault. 2013. "Machinic Milieus: Simondon, John Hart and Mechanology." *Disability History Newsletter*, (Fall): 1-5. <http://www.disthist.org/newsletter.htm>.

Heidegger, Martin. 2013. "The Question Concerning Technology." In *The Question Concerning Technology and Other Essays*, 3-35. San Francisco: Harper Perennial Modern Classics.

Hoel, Aud Sisel and Iris van der Tuin. 2013 "The Ontological Force of Technicity: Reading Cassirer and Simondon Diffractively." *Philosophy of Technology*, Vol 26: 187-202.

Leroi-Gourhan, André. 1973. *Milieu et Technique*. Paris: Editions Albin Michel.

Lafitte, Jacques. 1972. *Réflexions sur la Science des Machines*, introduction by Jacques Guillerme. Paris: Librairie Philosophique J. Vrin.

McLuhan, Marshall. 1994. *Understanding Media: The Extension of Man*. Cambridge, Mass. and London: MIT Press.

Merleau-Ponty, Maurice. 1968. *The Visible and the Invisible*, edited by Claude Lefort, translated by Alphonso Lingis. Evanston: Northwestern University Press.

Simondon, Gilbert. 2005. *L'Invention dans les Techniques Cours et Conférences*, edited by Jean-Yves Château. Paris: Editions du Seuil.

Simondon, Gilbert. 2009. « Entretien Sur la Mécanologie ». Introduction by Vincent Bontems. *Revue de Synthèse*, Vol. 130, Series 6, No. 1 : 103-132.

Simondon, Gilbert. 2009. "Technical Mentality." Translated by Arne De Boever. *Parrhesia: A Journal of Critical Philosophy*, Number 7: 17-25. <http://www.parrhesiajournal.org/>.

Simondon, Gilbert. 2013. *L'Individuation a la Lumière des Notions de Forme et d'Information*. Grenoble: Editions Gêrôme Million.

Simondon, Gilbert. 2014. *Sur La Technique 1953-1983*. Paris: Presses Universitaires de France.

Simondon, Gilbert. 2017. *On the Mode of Existence of Technical Objects*. Translated by Cecile Malaspina and John Rogove. Minneapolis: University of Minnesota Press.

Simondon, Nathalie. 2013. "Gilbert Simondon Biography." In *Philosophy of Information and Communication*, translated by Andrew Iliadis, 5. <http://philosophyofinformationandcommunication.wordpress.com/2013/06/30/gilbert-simondon-biography/>. Accessed 6/21/2014.

**Mechanological Dynamics in Jacques Lafitte
and Gilbert Simondon**

Thibault, Ghislain. 2017. "Filming Simondon: The National Film Board, Education and Humanism." *Canadian Journal of Film* Vol 26, No. 1, (Spring 2017): 1-23.

Vidler, Anthony. 1999. "Technologies of Space/Spaces of Technology." *Journal of the Society of Architecture Historians* Vol 58, No 3, Architectural History 1999/2000 (Sept. 1999): 482-486.

Wiener, Norbert. 1961. *Cybernetics: or Control and Communication in the Animal and Machine*. Cambridge: MIT Press.

Wiener, Norbert. 1965. *God and Golem, Inc.*. Cambridge Mass. and London: MIT Press.

DEVELOPING 'URBAN JUNGLE' AS AN INTEGRATED MODEL OF SURVIVAL: Learning from Nature in War Zones

Yasser El Masri
Georgia Institute of Technology

Abstract: This paper explores the relationship between conflict in the urban environment and natural systems of resiliency found in forests and jungles. Studying the different accounts of inhabitants of cities under siege during the Syrian Civil war, indicates that various sustainable practices were implemented within the built environment that helped inhabitants survive the devastating process. The innovative, circular economy allowed the inhabitants to survive their plight and lessened the intended effects of the destructive sieges. Drawing parallels with how forests and jungles utilize different natural systems, such as mycorrhizal networks, to increase resiliency, many lessons are inferred about sustainable resource management and efficient allocation in the face of different threats. The "Urban Jungle" is thus synthesized as a model that attempts to augment and maximize the practices inhabitants had devised through mimicking the model found in the natural jungle. Applying this model to conflict zones allows the evolution of survival tactics into a form of insurgent resilience, with wider socio-political ramifications on the survivability of the inhabitants, their political will, the effectiveness of the conflict, and sieges as a political tool.

Keywords: Sustainable design, urban jungles, low tech sustainability, peace building architecture, resilience

"I don't know how to deal with you: your ID has one face of hell and the other of paradise", as he compared my husband's birthplace of Baba Amr with his residency of Al-Mahatta, known for its large number of Christian inhabitants" (Al-Sabouni 2015)

INTRODUCTION

In the introduction to her book *The Battle for Home: The Vision of a Young Architect in Syria*, Syrian architect Marwa Al Sabouni attempts to study how the urban structure and demographic fabric of her hometown of Homs in Syria had actually exasperated the division between the various groups in the city and helped degenerate peace into a civil war. Homs is popularly known as the "capital of the Syrian revolution", and Sabouni states that the built environment is "not irrelevant to that question" (Al-Sabouni 2015). She raises an interesting notion in stating that "architecture offers a mirror to a community and in that mirror, we can see what is wrong and also find hints on how to put it right" (Al-Sabouni 2015). Sabouni paints a picture of Homs before the war as a metropolitan place that saw different sects of Syrians coexist with each other harmoniously with mutual respect. It is thus justifiable to wonder how a seemingly coexisting populace fell into the tragic reality that exists today. The case of Homs sees a pattern replicated all over major cities in Syria where a brutal regime is sowing sectarian discord and attempting to forcibly change the urban morphology and demographics of cities for its own political and sectarian gains.

The Syrian civil war that started as a civil uprising in 2011 and quickly turned armed after a

brutal government takedown is one of the twenty-first century's most tragic humanitarian crises (Marks 2018). The complexity of the conflict, with roots almost a millennium old, makes approaching it a particularly daunting task. This is effectively a conflict fifty years in the making since Hafiz Al Assad's coup in 1970 that brought a minority Alawite regime to the control of Sunni majority Syria under the guise of pan-Arabism. The sectarian angle taken by the regime saw the championing of the Alawite minority in all manners of government and any form of Sunni dissent brutally crushed (Tsurkov 2019). The 1982 Hama Massacres against agents of the Muslim Brotherhood being a very prominent example of this thinking that yielded tens of thousands of casualties (Allouche 2018). The dissent would remain prominent between the different sects of Syria, as the regime had actively attempted to feed into it to ensure its survival through its control of intelligence and secret service bodies. Introducing Alawite inhabitants from rural areas into specific neighborhoods in majority Sunni cities in the last 20-30 years and recruiting them for security and intelligence roles was another tactic the regime employed which gives a window into how an ideological and sectarian issue began to incorporate the built environment (The Syria Institute and PAX 2017, 17). The dynamics of altering the urban environment created a potential conflict zone that exploded in 2011 and spiraled into bloody conflict ongoing to this day. The makeup of Syrian cities with their segregated neighborhoods allowed the regime to selectively target and subjugate inhabitants in dissenting neighborhoods while ensuring and bolstering its presence in others.



Figure 1: Computer Rendering of the Homs Dream project (Zein 2014)

This divide in Sabouni's city of Homs was exemplified with the controversial Homs Dream project. A seemingly huge urban development project located in historic Sunni neighborhoods only sought to displace the mainly Sunni inhabitants in Homs in a sustained demographic change effort (The Syria Institute and PAX 2017, 19). The project was characterized by evictions and land seizures beginning in 2009 and was referred to by the inhabitants as "Homs Nightmare". The fact that the project did not approach the Alawite neighborhoods in the city gave it a sectarian angle and fed into a general feeling of discord among the two groups. This was evident when the Syrian Protests began in the city of Homs on March 18, 2011; the main call of the protestors was to remove Mayor Iyad Ghazal, who had largely supported the project. After the government forces cracked down on the protestors using paramilitary groups called "Shabiha", formed mainly of Alawite individuals, the conflict turned into an armed and sectarian one that led to the destruction of the Sunni neighborhoods in an almost systematic way. Government attacks would target uninhabited buildings that were empty and had no military value (The Syria Institute and PAX 2017, 19), for this was bombardment for the sake of destruction and not winning a military battle, which feeds into the idea of targeting the urban environment and controlling resources for political gain.

Elongated sieges with a specific purpose to alter the built environment through systematic destruction and demographic change present an important architectural question: How does architecture react to forced attempts of altering it? This paper takes the Syrian case as a model of a modern conflict with an angle, beyond military victory and control, that forays into the socio-political dimensions of the urban environment. The paper aims to show that a city under stress acts as a natural system and not as an artificial one. Studying how natural systems of congregation such as forests and jungles function, and why they succeed or fail, a model of sustainable urban resiliency dubbed "Urban Jungles" can be delineated. This model envisions the city and its relationships, resource supply, and allocation as a jungle or forest. It attempts to mimic

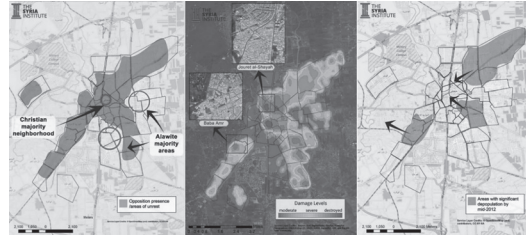


Figure 2: Map indicating areas of opposition in the city of Homs, destruction levels and subsequent depopulation (The Syria Institute, and PAX 2017)

natural systems' constant search for equilibrium in the context of urban environments under stress.

1. CITIES UNDER STRESS

The Oxford English Language dictionary defines a siege as "A military operation in which enemy forces surround a town or building, cutting off essential supplies, with the aim of compelling the surrender of those inside". Breaking down that definition shows there are three main facets to it. The first being a military operation and thus a direct threat to the built environment. The second being cutting off supplies, which involves all forms of requirements for life and its sustenance. The third being the compulsion of those inside to surrender, indicating a forced subjugation to political will. This can indicate that the nature of the action is one that involves putting a built environment under stress, in order to induce change within it by force.

The tactics employed in the Syrian civil war by the Syrian regime forces in particular display a barbarity inspired by medieval siege warfare (Shaheen and Wintour 2017). The general strategy is to besiege a city or town and then pummel it with various munitions many of which, according to the *Landmine and Cluster Munitions Monitor*, are internationally banned, such as cluster bombs and fuel-air bombs in the guise of "barrel bombs" (Cluster Munition Coalition 2015, 12). The siege could go on for years and food, fuel, and medical aid would be cut off from the inhabitants that could not escape. According to one account published in *The Guardian*, a Syrian army defector, who was involved in such a siege in the Damascus suburb of Daraya as an opposition fighter, reported that "Daraya was placed under tight siege in November 2012 where similar to the Ghouta offensive, food stocks dwindled. The defector describes how civilians picked grass from sidewalk cracks to pad out their thin watery stems. He is haunted by memories of children wasting away from starvation" (Al-Arian 2018). The siege of Daraya would go on for four years with the rebels finally surrendering in 2016 after making a pact with the government forces to evacuate to Idlib, a rebel-held Northern Province.



Figure 3: Drone Image of Tariq Al-Bab in Aleppo (TRT World and Agencies 2016)

This strategy would be employed time and time again by sides fighting in the war, causing untold suffering and casualties to those who endured these prolonged sieges.

Another facet of these strategies would be that electricity would be almost nonexistent. Electricity supply to besieged areas is quickly cut off when they are first surrounded, as a means of what Amnesty International calls the "Surrender or starve" strategy (Shaheen and Wintour 2017). This poses various risks, especially with the loss of refrigeration of food, as well as the loss of electric heating and cooling systems, which could prove devastating as the seasons pass. According to one account published in *The Guardian* during the siege of Eastern Ghouta by a survivor, "Fridges don't exist as part of our life. Anything that needs electricity is not used. Thank God we don't have cholera yet" (Shaheen and Wintour 2017). Fuel for heating and local electricity generation would also be cut off except for what smugglers could bring into the city, which would be at a much higher price. After the populace has been pummeled and succumbs to the siege, pacts with the regime would see the inhabitants evacuated in the now-infamous green buses to the last remaining pocket of resistance in the north-western province of Idlib (Denselow 2017).

Physical destruction of the built environment would only ensure the temporary displacement of a targeted population; ensuring the permanent eviction takes further steps. One facet of that were accounts of land registries that were intentionally burned down by regime forces to destroy any evidence of land ownership and deny returning inhabitants the right to their property (Chulov 2017). The regime went a step further to solidify the eviction when it issued a very controversial law called "Law Number 10" on the 2nd of April 2018. This law stated that property owners had thirty days to register and present proof of ownership of what was effectively now rubble (Al-Shami 2018). Failure to present that proof would result in the confiscation of property by the government with no compensation. This law would effectively forfeit targeted populations' right of return to the cities they had inhabited and allowed the Assad

regime to introduce new populations of loyalists into neighborhoods, as it redeveloped these areas according to its own agenda. With displacement, the destruction of evidence, and persecution, Iran, the Syrian regime's ally and biggest sponsor, has been utilizing this tactic to introduce Shiite families loyal to both regimes thereby replacing the original inhabitants. This has been seen in the area of the valleys between the Lebanese border and Damascus and even in Homs itself. For example, 300 Iraqi Shiite families have moved into Daraya, a suburb of Damascus, in an effort by the Syrian regime to create a belt of loyalists around the city to avoid any future threats (Chulov 2017). This puts into perspective the extent to which the Syrian regime wants to usurp the cities of Syria and evict their inhabitants. The question remains, how do the inhabitants of urban environments under threat resist?

1.1. THE ISOLATED SYSTEM: EMERGENCY ARCHITECTURE FOR SURVIVAL

In a traditional macro grid-supplied urban environment, a completely besieged city can be thought of as an isolated thermodynamic system in terms of resources. This system would have a finite amount of energy (resources), where energy cannot be created or destroyed only transformed. It would only move towards more disorder and loss over time as the energy is transformed, eventually attaining a level of high entropy. Entropy is the measure of the disorder within a system where the energy is in a state that is very difficult to harness. Under such a system, a siege tactic that isolates the system would serve its intended purpose of resource starvation as a function of time turning the system into one of high entropy. However, if the system finds a way to obtain energy from a seemingly infinite source from within the boundaries of the system, then the thermodynamic cycle is broken, and the system can move to a state of less disorder. In urban environments that are isolated, renewables such as solar and wind energy, rainwater, urban farms, and recycled materials can effectively break the isolation of the system and become a closed system. A closed system is a system where energy can pass into the system, while matter cannot due to the existing boundary layer. Under such a system, consumables traditionally supplied from outside the city limits, such as energy, water, and food are cut off due to the siege. Renewables, however, can still penetrate the siege when harnessed and utilized. This can impede the intended effects of the siege and allow a window of hope to those targeted.

There are plenty of examples of how Syrians were able to innovate in response to the barbarity of the sieges and effectively transform their environment from an isolated system to a closed one. These were

Developing 'Urban Jungle' as an Integrated Model of Survival

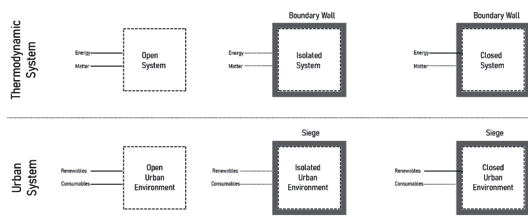


Figure 4: Thermodynamic and Urban Models are comparable in the way they manage resources (Author 2019)

developed as forms of emergency architecture that utilized at heart sustainable thinking about resources and survival modalities of spatial resistance. The system was comprised of many elements that worked together and transformed energy harnessed from consumables to renewables. Early warning systems using walkie-talkies and messaging apps allowed rudimentary communication between the inhabitants that not only gave civilians time to seek shelter, but also provided doctors and medical crews notice to prepare and be ready to deploy immediately. Another tactic was to relocate high-value targets, such as field hospitals to mountain grottos, or underground basements (Center for Civilians in Conflict 2016). One account from besieged eastern Ghouta indicated the utilization of an improvised solar oven by placing mirrors on a satellite dish and focusing sunlight through small mirrors on a hanging pot of metal, a system similar to solar towers (Arbini 2015). In the besieged town of Douma, residents used rudimentary solar panels to power a water pump and restore the water supply for the residents (Mohammad, 2017). Another account from Damascus by journalist Youmna Al Dimashqi indicates the use of rudimentary green roof gardens for planting food. Dimashqi reports the account of an inhabitant named Hamid that implemented this system on his rooftop, "At the beginning, I put sixty bags of dirt in a fifteen square meter (160 sq ft) area," said Hamid, "but when the blockade tightened, even more, I expanded the area to thirty square meters (320 sq ft). I planted things like arugula, radishes, parsley, cilantro, and lettuce. That's how I was able to avoid the crazy prices of the market" (Al-Dimashqi 2015). This account is a cogent example of reactive sustainable survival tactics utilized that if implemented on a larger scale could effectively diffuse the effectiveness of starvation tactics while providing a green roof cooling effect and urban farming potential. Fuel shortages essential for heating, cooking, and transportation were dealt with by extracting fuel from plastics rather than oil. The process involved melting the plastic that would produce a gas that would then be piped and cooled, which would produce a yellow liquid that could be used as an alternative fuel (Agence

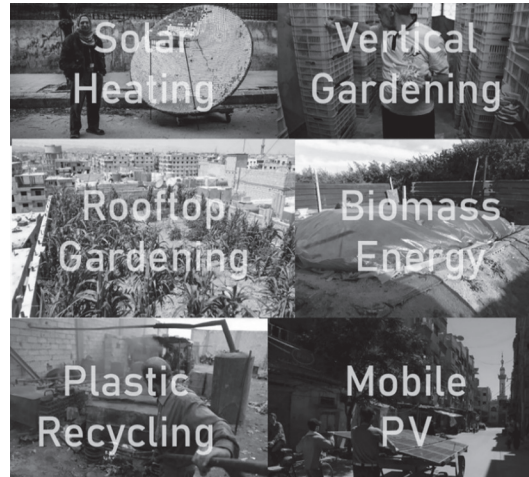


Figure 5: A myriad of rudimentary systems applied by people in conflict zones that embody perfect sustainable design thinking (Hall 2017; Shaheen & Wintour 2017; edited by the author)

France-Presse 2016). This process is not sustainable, as the plastics are consumables and there exists obvious safety and environmental hazards in the extraction and burning of diesel and plastics, however, it indicates to what length the management of resources had reached.

Combining these innovative systems transcends the immediate need for survival and becomes a show of resilience and political will. By opting to hold out and innovate to survive rather than be evicted, the inhabitants were, in fact, making a political and existential statement. Refusing to acknowledge the regime's authority, and refusing to forfeit their presence, is a form of insurgency and resistance by its own right. The major lesson this provides is that energy, food, and water in their various forms are often used as a tool of war and siege. Consequently, sustainable design practices have a natural role to play in conflict zones. The horrible experience of how people in the besieged areas in Syria were able to survive for such extended periods of time raises the notion of whether the built environment itself could "fight back" and were built in a way that would neutralize barbaric practices such as "Surrender or Starve". The idea would be that these practices would deter the effectiveness of such strategies to the point that they become unviable to those who would consider using them, effectively changing the rules of the game. Practices of sustainable design, such as rooftop urban farming, off-grid electrical use, and passive house cooling and heating, are all examples of low-tech rudimentary sustainable design systems. However, the question remains of how exactly these systems and strategies could be combined into a functioning ecosystem that would ensure energy, equity, and resilience on an urban level.

2. NATURAL JUNGLES: A MODEL FOR RESILIENCE

Architecture by nature is a complex art that transcends the empirical understanding of the sciences it is involved with. In engineering, we find notions of equilibrium guiding many processes with definitive answers that can be predicted (e.g., $a=a$). Architecture or successful architecture, on the other hand, should present a variable model, where it's more than the sum of its parts; a kind of architectural genesis rather than synthesis (e.g., $a=a+b$). This idea is integral to the philosophy that drives the architecture of conflict zones, as the building must answer and deal with a plethora of things more complicated than simply the physical attributes of the environment itself.

Architecture has a role in reacting to the challenges facing groups living in daunting conditions. Sustainable design thinking is, therefore, a major pillar that is required when managing meager resources to build resilience and enhance survivability. This thinking not only works to avert armed conflict through increased resource equity, but minimizes collateral casualties and suffering if conflict occurs. Aggressors would seek to limit or cut off resources to certain groups or, during actual warfare, target lifeline buildings such as food markets and water and electrical utilities, which would prove disastrous on a humanitarian level. The nexus of food-water-electricity is a sacred one in urban resilience models and, without established resource equity that would distribute these to different groups, conflict finds a breeding ground. Through providing resource equity to various groups, the sense of injustice that some social ethnic or religious groups would feel could be averted. This in turn, provides the extra layer of resilience to the inhabitants of the built environment during armed conflict, where architects can ensure that the built environment they designed is working to augment the survival of its inhabitants. This double role makes sustainability a major goal that must be implemented as an essential part of diffusing conflict and neutralizing it.

Resilience in architecture is a byproduct of an entire integrated assembly rather than simply a layering of elements. Thus, architectural and mechanical systems transcend beyond their obvious roles and become players in this ecology of conflict resolution and survival. Perhaps there is no better analogy or model of an ecology under threat of annihilation than jungles, forests, and deforestation. The Amazonian jungle, for example, has been dwindling due to deforestation at an average rate of approximately 19,613 km² a year between the years of 1995 and 2015 (Ometto et al. 2014, 576). This astoundingly large area is almost twice the size of the Middle Eastern country of Lebanon (10,452 km²). Yet, even with so much depletion, we still consider whatever is left of its original state the Amazon

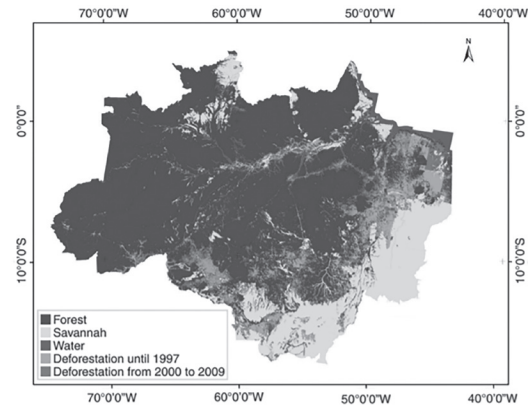


Figure 6: Decrease in the size of the Amazon Jungle over the years (Ometto et al. 2014)

“jungle”, hence still sustaining itself as it stands and not what it was. This would perfectly embody the idea that in a city embroiled in conflict, where certain parts of the urban environment are targeted or inevitably destroyed, what is left remains functioning rather than the entire system collapsing. Only parasites living off those trees would die, and, thus, we must remove this parasitic nature of dependency on a single building or utility, such as an electrical and water utilities, for supply. Rather than make all buildings parasites that live off these centralized buildings, each building becomes a tree in itself where if it falls, it only affects itself.

Furthermore, the nature of a jungle's decentralized resource transport and allocation networks present an exceptional model of how symbiotic relationships can help proliferate a system, while not making the dependency a liability. The roots of the trees are interconnected with underground fungal networks where they share nutrients and water called “Mycorrhizal Networks”, as seen in figure 7. This allows smaller trees in the more shaded part of the jungle that cannot photosynthesize, due to the extent of canopy and the lack of sunlight, to proliferate and survive (Grant 2018). Peter Wohlleben, author of the bestselling book *The Hidden Life of Trees: What They Feel, How They Communicate—Discoveries from A Secret World*, recalls an account of a gigantic beech tree stump that was felled around 500 years ago, but was still green with chlorophyll. This discovery led him to conclude that the only way this was possible was that the interconnected roots of the trees were still supplying the stump with sugar, keeping it alive in a botanical sense (Wohlleben 2016). Here, the parasites become part of the system, as they provide the interconnections between the trees for a small energy fee of nutrients. This newly defined parasitic nature becomes an important part of the ecology and the same idea can be applied to inhabitants

Developing 'Urban Jungle' as an Integrated Model of Survival

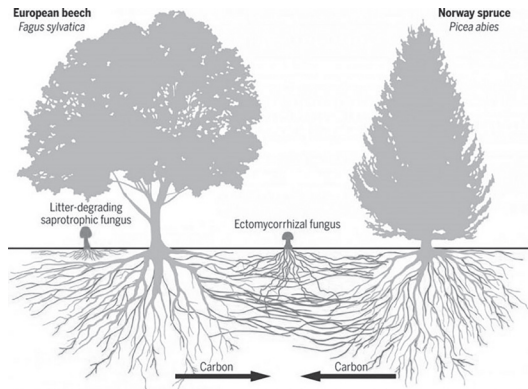


Figure 7: Forest trees interconnected through mycorrhizal fungal networks that can interlink numerous tree species. The hyphal networks provide an avenue for carbon to be transported between the trees (Van Der Heijden 2016)

of urban environments. They are the resource parasites that can play an integral role in helping interconnect the resources created and gathered by these low-tech sustainable systems from energy, water, and food, and distribute it intelligently where it is needed most to ensure the survival of the entire jungle.

Even when a natural jungle is under a sustained attack of deforestation or parasite infestation, the way its ecology is built helps it survive. When a tree is under threat it releases volatile organic compounds to warn others of an impending attack, which allows them to ramp up chemical production for defense (Karban et al. 2014, 45). Trees even utilize underground networks to send signals to each other, warning them of imminent threats (Babikova et al. 2013, 1). Douglas-fir trees, dying inside due to drought and western spruce budworms, have been found to transfer photosynthetic carbon to neighboring receiver Pine trees through the mycorrhizal networks. This aids in the recovery of the forest and its succession after a specific disturbance (Song et al. 2015, 2). This astounding look into the dynamics and relationships of forests and jungles allows us to see them as more than simply a congregation of trees, but as a true ecosystem that is far from static.

A jungle is not made of smaller jungles just as water is not made of smaller "waters", it is the result of the whole of its various elements that comprise it. With such thinking driving the analogy, buildings become the trees in which smaller natural elements thrive around and within. This idea of a balanced ecology transcends the mechanisms of dependency for survival and becomes a broader allegory for the idea that it could achieve self-sufficiency. For, if we cut down part of the jungle, we would have a smaller yet fully functional jungle, until the last tree is felled, whereupon the jungle ceases to exist (figure 8). A natural jungle, therefore, is an exceptional case study of resource allocation, not



Figure 8: Photograph indicating how the damage in a jungle would be confined to where the deforestation occurs (Gibbs et al. 2010)

unlike the way the urban environments in besieged Syrian cities functioned under resource stress and direct attack and it is based on these findings that we can construct a model of resilience.

2.1. URBAN JUNGLES

To translate these rudimentary applications of sustainable building systems into a dedicated urban resilience model, we must synthesize a new way of treating the relationship between cities, buildings, and resources modeled on the processes that occur in natural jungles and forests. This would see a nexus of the individual and the group work in tandem to help decentralize and give autonomy to people, in terms of resource independence and identity expression. Traditionally, cities are supplied by municipal water systems, food trucks, and electrical utilities through a large infrastructure that delivers these resources to every architectural unit or building (figure 9). However, this presents a vulnerability to the population as striking or controlling the utility or centralized resource would leave the entire populace at risk. To address this vulnerability, sustainable design thinking is needed to create resilience and equity. The urban system must abandon this "macro grid" thinking and replace it with a "microgrid" one that would help inhabitants of different neighborhoods feel they have control of their neighborhoods and resources.

The term "Concrete Jungles" has long been used to describe cities in terms of the physical material with which they are built. Concrete, a hard and cold material, implies a static, lifeless existence when, in actuality, buildings are far from that. It would be as misguided as assuming jungles are made of wood, rather than living, breathing trees. This one-dimensional focus on the materiality of an object must transcend into a

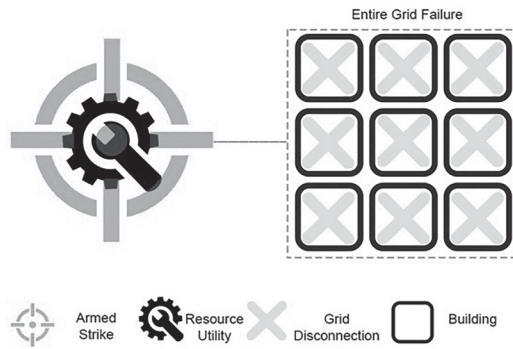


Figure 9: Model of traditional Macro Grid Utility Connected Urban Environment (Author 2019)

multidimensional understanding of its relationships. Thus, that term must evolve to a more modal description of "Urban Jungles" that can provide a case for both symbiotic and self-sufficient practices that can support conflict architecture. The evolution of this term is equally symbolic in the evolving sense of how we approach the identity and role of an urban environment. The grand concept that lies at the heart of this idea is that change starts within the smallest scale, in this case a self-sufficient tree. As more similar trees (buildings) exist, they congregate to form the urban jungle that is represented as an urban district with interconnected systems sharing resources created by this tree. This would ensure a system of elements that becomes more than the sum of its parts, as this urban jungle or district would play a role in the expression of identity of the trees. A jungle for example of Palm or Kapok trees would be different than a jungle or forest of Elder or Elm, yet functioning equally the same. This translates into non-homogenous societies, where the expression of identity is crucial as a form of resilience and a way to mitigate the feeling of persecution felt by groups under sustained attack.

Under such a design philosophy, sustainability is not layered into the buildings in the guise of its separate systems as is the norm, but the driver behind building a balanced ecology, where all the various elements symbiotically work together to create this "jungle" (figure 10). This is a testament to the resiliency of the system that is both reliant and independent at the same time. Decentralizing macro grids by replacing or augmenting them with micro-grids of different resources created by low-tech rudimentary sustainability applications that weave within buildings is no different from Mycorrhizal networks ensuring the tree feeds the jungle and the jungle feeds the tree, whichever one fails first. These networks would also provide communication between the different buildings to prepare, allocate, and minimize the damage.

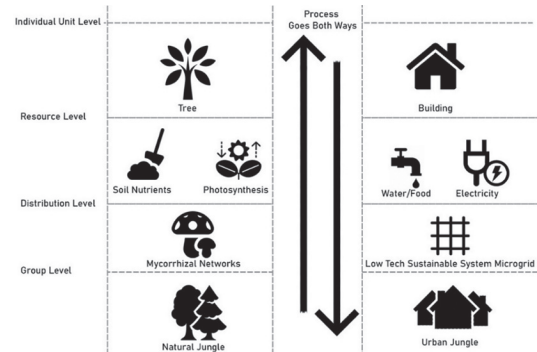


Figure 10: Urban Jungle Model indicating how it builds resilience through a process that goes both ways (Author 2019)

Driven by such a model the urban jungle can proliferate, grow, and expand in a resource-sustainable way due to processes embedded within its ecology. However, if the authority were to "deforest" the jungle, it would not fall in a domino-like effect but would isolate the direct damage and mitigate the collateral and indirect damage to other trees, while being sustained by these other "trees" (figure 11). This system would work from the ground up, from micro to macro, to provide the failsafe against systematic conflict or persecution by authorities (macro to micro), through decentralizing resources and empowering the populace.

However, it is important to indicate that this resiliency only buys time in the face of a sustained threat. In the end, the jungle or city can only fend off a sustained attack long enough. Here, it is the collective responsibility of others not involved in the threatened system to utilize the time the resiliency has bought to understand the crime that is occurring and work actively to stop it. Just as people today protest deforestation and enact laws to protect jungles and forests, the same must be applied and enforced in the context of urban

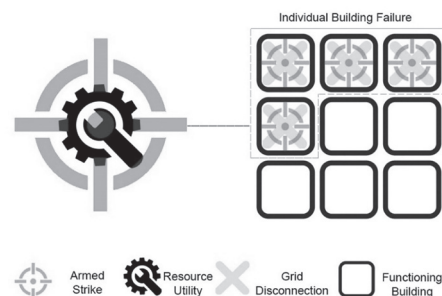


Figure 11: Evolved "Urban Jungle" model that is independent and resilient from Macro Grid and Utility-Based strikes or control (Author 2019)

Developing 'Urban Jungle' as an Integrated Model of Survival

environments. Cities are more than concrete jungles, they hold within them the life, memories, histories, and future of all who live within them. These troves of humanity must be protected at all costs. The world has watched for years the heroic survival of both the people of Syria and failed them time and time again. This model offers a blueprint for resilience in the hope that, if this ever occurs again anywhere in the world, it will buy those under threat enough time for the world to finally understand its role in saving them.

CONCLUSION

Cities and their dynamics are no exception to natural systems. Urban jungles attempt to create independence

for the groups that inhabit these islands as energy justice, sustenance, and equity, and pave the way to social and economic independence. This has a direct effect on the socio-political dynamics of the ruled vs. the ruler and empowers these communities to stand up for themselves. Cultivated from the Syrian model, urban models of resilience give people the chance to express without succumbing, withstanding the surrender and starve strategy for years. This paper has shown this model of sustainability as a powerful multilayered tool that goes beyond simple resource management and conservation and has a socio-political and economic factor that can change the reality of many under threat around the world.

REFERENCES

- Al-Arian, L. 2018. "How the Syrian Regime Keeps Winning Territory, From an Army Defector's Perspective." *National Public Radio*, March 24, 2018. <https://www.npr.org/sections/parallels/2018/03/24/596575357/how-the-syrian-regime-keeps-winning-territory-from-an-army-defectors-perspective>.
- Al-Dimashqi, A. 2015. "Do-It-Yourself Alternative Energy in Besieged al-Ghouta—Syria Deeply." *The New Humanitarian*, October 20, 2015. <https://www.newsdeeply.com/syria/articles/2015/10/20/do-it-yourself-alternative-energy-in-besieged-al-ghouta>.
- Al-Sabouni, M. 2016. *The Battle for Home: The Vision of a Young Architect in Syria*. London: Thames & Hudson. Google Books.
- Al-Shami, L. 2018. "Syria's Shock Doctrine." *Al Jumhuriya*, April 23, 2018. <https://www.aljumhuriya.net/en/content/syrias-shock-doctrine>.
- Allouche, Y. 2018. "The 1982 Hama Massacre." *Middle East Monitor*, February 12, 2018. <https://www.middleeastmonitor.com/20180212-the-1982-hama-massacre/>.
- Arbini, J. 2015. "Ingenious Invention in Besieged Eastern Ghouta: Solar Concentration Heater." Filmed May 2015 in Eastern Ghouta, Syria. Video, 06:03. <https://www.transterramedia.com/media/62283-ingenious-invention-in-besieged-eastern-ghouta-solar-concentration-heater>.
- Babikova, Z., L. Gilbert, T.J.A. Bruce, M. Birkett, J.C. Caulfield, C. Woodcock, J.A. Pickett, and D. Johnson. 2013. "Underground Signals Carried Through Common Mycelial Networks Warn Neighboring Plants of Aphid Attack." *Ecology Letters* 16, no. 7 (July): 835–843. <https://doi.org/10.1111/ele.12115>.
- Center for Civilians in Conflict. 2016. *Waiting for No One: Civilian Survival Strategies in Syria*. Washington: Center for Civilians in Conflict.
- Chulov, M. 2017. "Iran repopulates Syria with Shia Muslims to Help Tighten Regime's." *The Guardian*, January 13, 2017. <https://www.theguardian.com/world/2017/jan/13/irans-syria-project-pushing-population-shifts-to-increase-influence>.
- Cluster Munition Coalition. 2015. *Cluster Munition Monitor 2015: Special Five-Year Report*.
- Denselow, J. 2017. "Syria's Green Buses: Symbol of a Seismic Shift." *Al Jazeera*, March 22, 2017. <https://www.aljazeera.com/indepth/opinion/2017/03/syria-green-buses-symbol-seismic-shift-170321120600909.html>.
- France-Presse, Agence. 2016. "Besieged Aleppo turns to Dangerous 'Alternative' Fuels." *The National*, September 18, 2016. <https://www.thenational.ae/world/besieged-aleppo-turns-to-dangerous-alternative-fuels-1.232588>.
- Gibbs, H. K., A.S. Ruesch, F. Achard, M.K. Clayton, P. Holmgren, N. Ramankutty, and J.A. Foley. 2010. "Tropical Forests Were the Primary Sources of New Agricultural Land in the 1980s and 1990s." *Proceedings of the National Academy of Sciences* 107, no. 38 (September): 16732–16737. <https://doi.org/10.1073/pnas.0910275107>.
- Grant, R. 2018. "Do Trees Talk to Each Other?" *Smithsonian Magazine*, March 2018. <https://www.smithsonianmag.com/science-nature/the-whispering-trees-180968084/>.
- Hall, N. 2017. "Civilian Survival Strategies in Syria." *The New Humanitarian*, June 17, 2016. <https://www.newsdeeply.com/syria/articles/2016/06/17/civilian-survival-strategies-in-syria>.
- Karban, R., L.H. Yang, and K.F. Edwards. 2013. "Volatile Communication Between Plants That Affects Herbivory: A Meta-Analysis." *Ecology Letters* 17, no. 1: 44–52. <https://doi.org/10.1111/ele.12205>.
- Marks, J. 2018. "Why Is There a Civil War in Syria?" *History.com*, September 14, 2018. <https://www.history.com/news/syria-civil-war-assad-rebels>

- Mohammad, H. 2017. "Solar Solution Brings Water to Besieged Syria Town." *Phys.Org News*, June 21, 2017. <https://phys.org/news/2017-06-solar-solution-besieged-syria-town.html>.
- Ometto, J.P., A. Aguiar, S.R. Centre, and L.A. Martinelli. 2011. "Amazon Deforestation in Brazil: Effects, Drivers, and Challenges." *Carbon Management* 2, no. 5: 575-585. <https://doi.org/10.4155/cmt.11.48>.
- Shaheen, K. and P. Wintour. 2017. "Facing disaster': Children Starve in Siege of Syria's Former Breadbasket." *The Guardian*, November 24, 2017. <https://www.theguardian.com/world/2017/nov/24/syria-eastern-ghouta-siege-talks>.
- Song, Y.Y., S.W. Simard, A. Carroll, W.W. Mohn, and R. Zeng. 2015. "Defoliation of Interior Douglas-Fir Elicits Carbon Transfer and Stress Signaling to Ponderosa Pine Neighbors Through Ectomycorrhizal Networks." *Scientific Reports* 5, no. 1: 8495. <https://doi.org/10.1038/srep08495>.
- The Syria Institute and PAX. 2017. *No Return to Homs: A Case Study on Demographic Engineering on Syria*. Washington DC: The Syria Institute.
- TRT World and Agencies. 2016. "Drone footage shows devastation in Syria's Aleppo." *TRT World*, October 8, 2016. <https://www.trtworld.com/mea/drone-footage-shows-incredible-destruction-of-aleppo-202362>.
- Tsurkov, E. 2019. "Between Regime and Rebels: A Survey of Syria's Alawi Sect." *The New York Review of Books*, July 22, 2019. <https://www.nybooks.com/daily/2019/07/22/between-regime-and-rebels-a-survey-of-syrias-alawi-sect/>
- Van Der Heijden, M.G.A. 2016. "Underground Networking." *Science* 352, no. 6283 (April): 290–291. <https://doi.org/10.1126/science.aaf4694>.
- Wohlleben, P. 2016. *The Hidden Life of Trees* (Vol. 20). Vancouver BC: Greystone Books.
- Zein, L. 2018. "A Real-Estate-Led Demographic Destruction in Damascus And Homs." *Artalk Revue* 3 (Winter): 1–7. <https://artalk.cz/wp-content/uploads/2018/12/AR-3-EN-135489.pdf>.

DRESSMAKING TECHNIQUES FOR PNEUMATIC FORMS

Virginia Ellyn Melnyk
Tongji University, Clemson University

Abstract: This paper explores a process for digitally designing doubly curved geometry out of flat textiles. The development of computational modeling techniques, such as NURBS and sub-division modeling, has made it easier to create complex curvature in the computer. Yet fabrication methods and materials are still catching up on the ways to fabricate these types of complex geometries, particularly when working with woven textiles that have little or no stretch. These doubly curved surfaces are typically achieved by complex panelization patterns that can closely approximate the curvature. For this research, complex panelization is exchanged for more simplified patterns and articulate sewing techniques as a new way to create curvature. Inspiration for working with shaping textiles is drawn from the traditional craft of dressmaking, in which two-dimensional fabrics are cut and sewn in different ways to fit around the curvature of the human body. These techniques from dressmaking also allow for other decorative qualities to emerge from the fabric manipulations. The project uses computational modeling software from the fashion industry for its integration of these sewing techniques into a three-dimensional digital design environment and seamlessly output patterns for production. This project explores the possible use of these programs and workflow for architectural pneumatics design. The results are compared to the computer designs to better understand the deviation between the digital and physical models. Three prototypes are created; that each explore different techniques as a test set. They use various manipulations of the techniques to study their possible advantages to create shaping. The goal is to adapt the techniques and computational tools from the discipline of dressmaking, developing a new workflow to designing complex curvature on architectural pneumatic membranes.

Keywords: Computational design, fabrication, pneumatic, membranes, sewing

INTRODUCTION

Pneumatic structures reached a high level of popularity in the radical architecture of the 1960's, and has continued to fascinate architects as seen in a recent publication *Bubbletecture: Inflatable Architecture and Design*; the book highlights art, industrial design, and of course pneumatic architecture (Francis 2019). Perhaps this new interest is because of computer modeling and the three-dimensional forms that these NURBS and Sub-division modeling can easily produce. The geometries of so called *blobitecture*, that is curvy and bulbous, is possible to build with some pneumatic membranes. Pneumatics are also light weight which provides reduction in carbon footprint as they are easy to transport and build, though they have different construction constraints than typical architecture. They can be sewn out of two dimensional textiles, which is in contrast to the desired resultant form of the double curved geometry. Fabric manipulation techniques from dressmaking, such as pleats, darts, and gathers; are used on dresses and clothes to create shaping around the curved forms of the body. Dressmaking is traditionally a household feminine practice, which is perhaps why it has yet to be much explored as a possible approach to architectural design. Three-dimensional CAD-CAM software for fashion design

offers new computational methods for integrating the dressmaking sewing methods and pattern making techniques into the architectural design process. Utilizing Clo3D, as a tool to design and integrate sewing techniques for approximate double curvature on architectural pneumatic structures, can allow for a workflow that dialogs back and forth easily between the pattern output and the simulation of the three-dimensional design. The goal is not to create a complex pattern of panelization pieces but to create simple panels which are sewn in different ways to create this curvature. As a result, they are not smooth minimal surfaces but with desired decorative expression of the fabrics' materiality. Three prototypes were created to explore various techniques of sewing darts, pleats, tucks, and gathers (figure 1). The results are analyzed for their details and a side by side comparison of similarity between the physical to the digital simulations, to get a better understanding of the deviation in the results. The potentials of these techniques are in their early phases, but they ultimately explore a new, novel approach for integration of techniques from the discipline of dressmaking into the workflow and fabrication of architectural pneumatics.

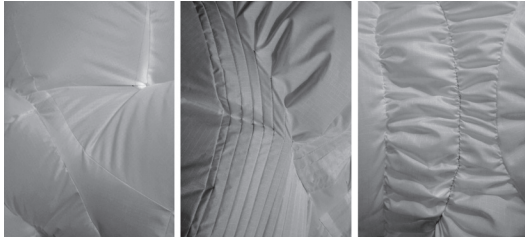


Figure 1: Detail photos of prototypes. (Author 2019)

1. PNEUMATICS

1.1. HISTORICAL CONTEXT

First records of inflatable structures begin with hot air balloons from the mid-eighteenth century in France, reaching a large popularity in the 1960's with speculative designs by radical groups such as Archigram, Ant-farm, and Utopie (Topham 2002). These architectural activists hoped to reject the hard concrete of Brutalism with new softer materials that were temporary, mobile, and ephemeral. In 1967, The University of Stuttgart, Germany, held the 1st International Colloquium on Pneumatic Structures between May 11th and 12th (Dessauce 1999). Shortly after in 1968, Utopie's *Structures Gonflables* exhibition took place in Paris. The 1970 World's Fair in Osaka, Japan, was an exuberant display with several pneumatic structures, including the Fuji pavilion by Yutaka Murata and Maroru Kawaguchi (McLean 2015).

1.2. CURRENT INTEREST IN PNEUMATICS

Although there has been some lasting interest in pneumatic design, it hasn't seen the same exuberance of the 1960's. Walter Bird continued to develop his designs from the 1960's with his company Birdair Structures Inc. in Buffalo, New York. He developed many large free span structures with pneumatics, often for pools, tennis courts, and military buildings. In the art world, artist like Yayoi Kusama playfully utilized brightly colored polka dot inflatables in her work (Topham 2002). For these same playful qualities, architects such as Atelier Zundel Cristea have adapted the use inflatables for their temporary structures (Cristea 2016). Other qualities, such as the ephemeral light that can penetrate through a fabric membrane, have been explored in the pneumatic structures of Architects of Air and Pnuehaus (Francis 2019). There are some architecture firms exploring pneumatics for their reduced amount of material, which can be more sustainable than traditional building methods, as it reduces carbon footprint during transportation, construction, and overall material consumption. Furthermore, because of the fascination with new technology, contemporary architects are

using computer aided parametric design software such as Grasshopper and Kangaroo to aid in the design of paneling systems for pneumatics. But much of the design process is ultimately dependent on a feedback loop between prototyping and digital design (Thomsen 2019). The time and energy to make prototypes as well as the use of lots of materials in the production of failed design tests is a wasteful process. In addition, much of the research is still focused on form finding and optimization of paneling to create smooth membranes. For example, *Inflated Restraint*, a project by CITA, explores a free-form membrane and a minimal cable restraint. The project utilizes Kangaroo for Grasshopper to create new panelization patterns for performance of a smooth membrane. (Thomsen 2019).

1.3. TECHNICAL CONSTRAINTS OF PNEUMATICS

Pneumatic membranes are fully in tension. Frei Otto studied soap bubbles, which are pneumatic membranes, for their form that naturally evenly distributes the pressure across the membrane and forms a sphere (Dent 1972). This distribution of pressure forces the material out from the center and shapes the membrane into a circle in cross section. For example, given a cube that is inflated, the cross sections would push out evenly and attempt to achieve a circle in shape (figure 2). This means that pneumatic structures made from two-dimensional woven fabrics are being evenly pressurized and they will always try and achieve a double curved surface. The result is that non-stretch fabrics will have points where there is high pressure on certain parts of the fabric and others with less pressure, resulting in the high pressured fabric being in tension and wrinkling in other parts where the fabric is more loose. This is controlled by the exactness of the patterning and panelization to the desired curved form. As a result, instead of trying to hide these effects, this research allows the material to express these types of forces by encouraging moments of smooth, highly tensioned fabric and allowing wrinkling. These elements expressed on the surface can potentially be decorative and ornamental.

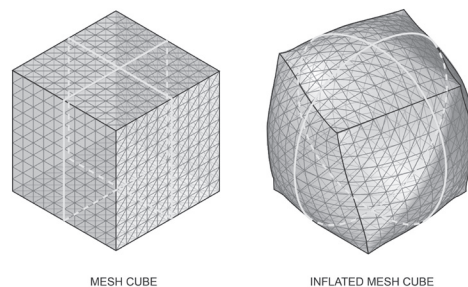


Figure 2: Simulation of inflated cube showing cross sections. (Author 2019)

2. DRESSMAKING

2.1. HISTORICAL CONTEXT

Dressmaking methods have changed over time with different fashions, styles, and development of new technology, but the basic techniques of manipulating fabric to form over the curvatures of the body for fitting remain the same. Dressmaking has also historically been feminine work and was one of the few early careers available for tradeswomen in the mid-1800s (Gamber 1997). Often, this relationship to femininity has made the craft in dressmaking something that is overlooked in research and history (Burman 1999). Moreover, dressmaking in particular has the potential as being relevant to architectural design for pneumatics, but perhaps has yet to be discussed partially; because of the low percentage of female representation in the field.

2.2. TECHNIQUES

Darts are used to fit fabric around the curves of the body (Talbot 1943). Triangular or diamond shaped slits are cut into the fabric and sewn back together forming the two-dimensional fabric into a three-dimensional shape. This technique is often used around the bust, hips, small of the back, or on necklines to create a concave fitting (Talbot 1943). For example, in a fitted block dress, a few darts at the small of the back, the neck, and in the torso area transform simple cuts of the fabric into a fitted waistline, while allowing more fullness in the bust and hips (figure 3).

Tucks also control the fullness of the fabric by, instead of cutting away fabric, folding and stitching parallel lines to reduce surface area (Talbot 1943). This is more decorative and can create thickness and structure in areas as well. Tucks are often seen on delicate sheer fabrics, such as in undergarments, necklines, yokes, and on blouses.

Pleats are often used to create dramatic contraction and expansion of fabric for skirts. Pleats fold the fabric over itself in small repeating layers. There are several different types of pleats depending on how

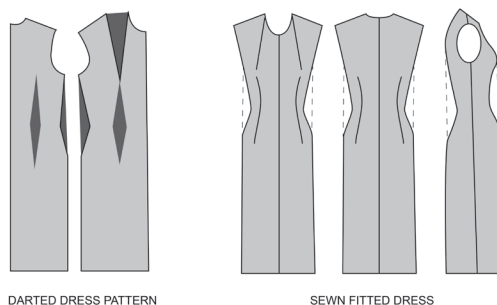


Figure 3: Fitted dress made with darts. (Author 2019)

the fabric is folded, for example, knife and box pleats (figure 4). Top, middle, and bottom layers, can overlap at varying amounts. The most common pleat is the full pleat, where all the layers are folded to the same length (Shoben, 1980). Some pleats are given a top stitch to emphasize the folds or keep the folds together for a length down the fold.

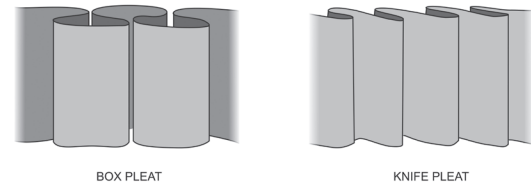


Figure 4: Diagram of knife pleat and box pleat. (Author 2019)

Gathering is used to create fullness, by sewing a longer fabric to a shorter piece of fabric. A running stitch is sewn through the fabric. The thread is then pulled to bunch the fabric up along the stitch until desired length is achieved to match the shorter piece of fabric (Talbot 1943). This technique results in a softer ruffled look, compared to the ordered layering of pleats (figure 5). This is also often used on skirts, necklines, and on puffed sleeves (Talbot 1943).

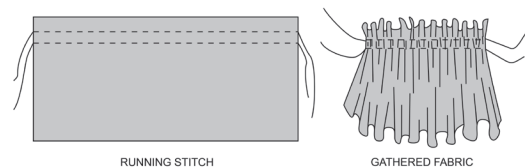


Figure 5: Diagram of gathering. (Author 2019)

Ruching is a type of gather that bunches fabric along a stitch line but in the middle of the fabric rather than along a seam. It can also include elastic to have more flexibility for movement. Ruching creates fullness and can be used more decoratively such as on the bodice of dresses or to create modesty on typically tight fitting clothing such as bathing suits. It can be sewn in repeating parallel lines to create texture and visual appeal.

2.3. DIGITAL TOOLS

Computational modeling has been integrated into the fashion industry; these types of three-dimensional modeling software open the possibilities for faster design and streamlined production. There are several software available such as: Browzwear, Vstitcher, Clo3D, Marvelous Designer, and more. For this project Clo3D was used. Each program has many similarities.

They are based on CAD-CAM modeling, utilize mesh modeling, and they have built-in physics simulations to allow for previews of the designs with real world material properties and forces. The physics simulation is more specific to the textile industry than that of Kangaroo or MAYA, as there are preset fabric properties to apply to the simulations. There are also many environmental simulations such as gravity and wind that can be applied. There is also a feature to add pressure to simulate inflation, which is useful for designing pneumatic forms. Furthermore, there are built-in ways to visualize the stress and strain on a material. This is integrated into the program to get the fitting correct but can also be used to explore the pressure points on a pneumatic model. The necessary tools to create sewing, earlier discussed techniques such as pleats, tucks, darts, and gathers are integrated into the program to make the workflow of dress designs easy. The program works in a two-viewport mode, where you can simultaneously preview the three-dimensional simulation and the two-dimensional pattern (figure 6). While using Clo3D, it is useful to have experience and understand pattern making and three-dimensional digital modeling, as well as knowledge of how paneling techniques and unrolled geometry relate to three-dimensional models. The two viewport mode also allows for a seamless back and forth workflow, where you can edit the pattern and the three-dimensional model changes in response. This creates a design method where the pattern is not just an output of a three-dimensional design but can be the source of the design. Nevertheless, these tools and techniques can create a new approach to the design methodology of pneumatics.

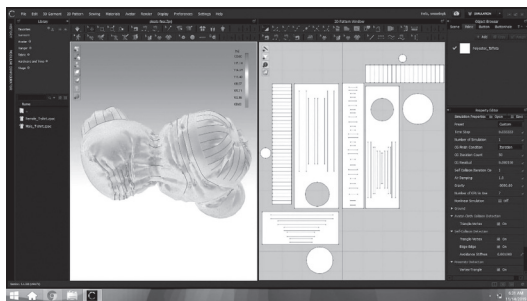


Figure 6: Image of Clo3D. (Author 2019)

3. GOALS

3.1. SIMPLE PATTERNS COMPLEX SEWING

Through a set of three pneumatic prototypes, a few ideas are explored. Mainly reducing the need for complex pattern generation but adding the more articulate sewing techniques from dressmaking, just

a few rectangular sized pieces of fabric and circles to close the ends were used to generate the designs. Each of the prototypes focuses on only one type of dressmaking technique at a time (figure 7) to allow for experimentation in size, spacing, and execution of the technique. The manipulation of these can result in different effects on curvature and form. Clo3D allows you to work from the pattern so most of the design came from the pattern design and the three-dimensional result was not predetermined, but a result of the play of the variations in stitching. Moreover, by adapting dressmaking techniques to architecture, the hope is to ultimately create more expressive qualities in the fabric rather than hiding it and developing a new aesthetic quality for pneumatic designs that challenges the typical approach of smooth membrane structures. Finally, through this process a new workflow is developed by using the three-dimensional computer software, from the fashion industry, from digital design, to simulation, to pattern, to physical models, without the need for several prototypes, creating a new streamlined process. The physical prototypes are compared with the computer simulations to see how closely the final results are to the software simulations, to get a better understanding of the success of this process.

4. PROTOTYPES

4.1. DARTS

The first prototype explores darts as a way to generate and shape through convex forms. The pattern created uses eight pieces of fabric, four rectangles and four circles. The darts are explored differently in each of the rectangular pieces of fabric to test the possible results and the forms that can be generated. One of the larger pieces uses triangular edge darts and they graduate in size to see the effect of asymmetry (figure 7). I had predicted that this would create a twisting effect, but it did not. The other larger piece uses diamond shaped darts in the center of the fabric lined in a row to create a pinch in the middle and bulging at the sides. This effect was successful and reflected the appearance of the simulated model. The smaller pieces explore both edge

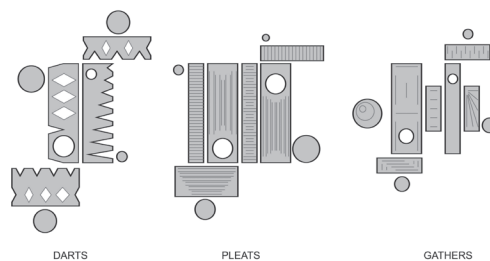


Figure 7: Diagram of pattern designs for the pneumatic prototypes. (Author 2019)

darts and central darts, with different spacing and sizes. Since darts do not have much overlap in the fabric or create too many wrinkles, the resulting model appeared mostly smooth, although at the points of extreme curvature, the darts on the fabric appear to bunch a bit and perhaps the prototype is not as smooth as a more panelized model. Perhaps working with smaller darts would produce a more refined approximation of curvature (figure 8). The shape seems boxier as the fabric is approximating the curvature through the air pressure forcing it from the center to a circular curve in section. Overall, the general form of convex and concave curvature is successful at creating complex curvature from a few pieces of fabric.



Figure 8: Pneumatic Darts Prototype. (Author 2019)

4.2. PLEATS AND TUCKS

The second prototype explores pleats and tucks. The pleats fold the fabric into three layers, thus the design is dependent on the proportions of thirds. The length at the open end of the skirt is three times that of the pleated end. The pleats in this design are used on the edges because of this drastic scalar difference between the pleated and the open end of fabric. The pattern has four long pieces in the main body and two smaller ones. The pleating being at the ends results in the circular pieces used there being smaller. On the longer pieces of fabric, parallel tucks are used to create a similar overlapping effect of pleats and make the fabric contract in size (figure 7). Different sizes of pleats and tucks are used, as well as lengths, to explore their potential effects on curvature. The resulting physical prototype sees more emerging qualities of the fabric, due to the fact that the nylon fabric that was used has thickness. The layering of fabric on the tucks and pleats, creates more rigidity in the form, which inflates to a boxier look. This unexpected structure is not well represented in the simulated computer three-dimensional model. Furthermore, this rigidity is very

apparent when touching the fabric and feeling bumps created by the folds. Also the translucent quality of the fabric is not well represented in the computer model, but the result of the overlaying of fabric created moments of more opacity in the fabric. Finally, the pleats do create unique wrinkles, texture, and expression of the fabric, as it shapes into the pressurized three-dimensional form (figure 9).



Figure 9: Pneumatic Pleated Prototype. (Author 2019)

4.3. GATHERING AND RUCHING

The final prototype utilizes gathering and ruching to create a ruffling effect. Gathering and ruching can be a bit more free-form in the proportions of expansion versus contraction. To simplify the set of results, the gathering ratio was set to fifty percent so that all the lengths would be gathered to be one half of their original length. This constraint helped focus the testing to the spacing, and patterning of the gathers and ruching. The design used six rectangular pieces of fabric, two long pieces and two shorter pieces (figure 7). Gathering is used at the seams to reduce the edge length of the longer pieces to match with the shorter pieces and ruching is used in the middle of the fabric in each piece to test different approaches to manipulating curvature. Parallel lines, shifted parallel lines, radial lines, and switching between x-axis and y-axis lines are all tested. These techniques result in several unique effects. Several small parallel ruches did create some curvature in the form, but overall it creates more billowing effects throughout the form. The physical prototype ultimately has many wrinkles and puckering in the fabric due to the cinched effects of the gathering and ruching; it almost never reaches any moments of smooth geometry. This creates a grotesque, but beautiful design, where the wrinkles really generate an overall surface texture and emergent qualities in the membrane's materiality (figure 10).

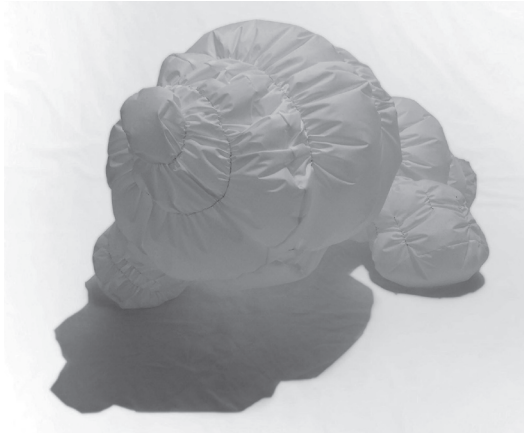


Figure 10: Gathered prototype. (Author 2019)

5. ANALYSIS

5.1. COMPARING THE DIGITAL TO PHYSICAL RESULTS

The resulting prototypes were fabricated based on the computer-generated three-dimensional models; the prototypes each have their own merits in creating texture and curvature. Whether the use of these simulations can result in a successful prediction is important to understand, as this could reduce the amount of prototyping and testing that is often needed in the design of pneumatic structures. The digital and physical models are compared side by side, with photographs of the physical prototype next to a rendering of the digital model from a similar angle (figure 11). The results show that some extra gravity and material weight are not expressed in the digital simulation. Certain parts of the digital model sag more due to simulated material weight, while other parts seem to float more than the physical. As well, the material build up in the tucks in the middle of the prototype became more rigid. Overall, it does seem that the simulations and the models do have a good amount in common in terms of the overall form finding and basic understanding of the resulting form. Adjustments can be made to the density of the mesh of the model to become more detailed and have a higher quality resolution, which could result in even better predictions. Ultimately it is the emergent material properties, such as light and material thickness, that really need to still be investigated through physical prototyping.

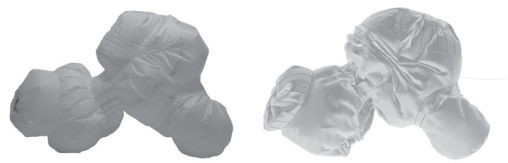


Figure 11: Photos side by side comparison of physical and 3D computer simulation. (Author 2019)

CONCLUSION

This set of pneumatic prototype, utilizing different types of dressmaking techniques and fashion design software, offers a new approach to designing pneumatic structures. The results create a new workflow by adapting software from the discipline of fashion design. By working with the Clo3D software one can work from the pattern to the design, rather than the pattern being a result of the form. The software also does a good job simulating with material properties and physics to predict the resultant form of the model. This allows for a feedback loop in the computer, rather than producing many prototypes to see the design results. The software streamlines production by being able to plot patterns with all the necessary information about cut lines, stitch lines, and seam allowance. Ultimately, working with this new software for pneumatic architectural purposes has the potential to create new methods of working and form finding for these types of designs with textiles. By using the traditional sewing techniques from dressmaking, curved geometry was created without requiring complex paneling of many pieces of fabric. Darts, pleats, tucks, and gathers each created different effects and did result in creating the desired three-dimensional curvature. Darts make more concave forms, while pleats allow quick expansion and contraction of fabric, and gathers create a more free-form and the most wrinkles in the fabric. These sewing techniques generate new opportunities for textures to be part of the design and expression for pneumatic structures. Future research could continue to explore more dressmaking techniques with the potential to create other types of geometry, as well as combine different techniques together to achieve an more complex structure overall, with varying qualities across a form. This research has a lot of potential to affect the way architects design with pneumatics and textiles. The next phase is to test these results at an even larger architectural scale.

REFERENCES

- Bergman, Barbara. 1999. *The Culture of Sewing: Gender, Consumption, and the Dressmaking Trades*. Oxford: Berg.
- Cristea, Irina and Gregoie Zundel. 2016. *Time For Play: Why Architecture Should Take Happiness Seriously*. New York: Actar Publishers.
- Dent, Roger N. 1972. *Principles of Pneumatic Architecture*. New York: Halstead Press Division John Wiley & Sons, Inc.
- Dessauce, Marc, ed. 1999. *The Inflatable Moment: Pneumatics and Protest in 68*. New York: Princeton Architectural Press; New York: The Architectural League of New York.
- Francis, Sharon. 2019. *Bubbletecture: Inflatable Architecture and Design*. New York: Phiadon Press Inc.
- Gamber, Wendy. 1997. *The Female Economy: The Millenary and Dressmaking Trades, 1860 – 1930*. Urbana: University of Illinois.
- Talbot, Constance. 1943. *The Complete Book of Sewing; Dressmaking and Sewing for the Home Made Easy*. New York: Book Presentations.
- Thomsen, Mette Ramsgard, Martin Tamke, Phil Ayres, and Paul Nicholas. 2019. *CITA Complex Modeling*. Toronto: Riverside Architectural Press.
- Topham, Sean. 2002. *Blowup: Inflatable Art, Architecture, and Design*. New York: Prestel.
- Shoben, Martin and Janet Ward. 1980. *Pattern Cutting and Making Up: The Professional Approach*. London: Batsford Academic and Educational Limited.
- McLean, Will and Pete Silver. 2015. *Air Structures*. London: Laurence King Publishing.

PERFORMANCE-BASED FACADE DESIGN TOOL: Approach for Automated and Multi- Objective Simulation and Optimization

Mahsa Minaei
University of Massachusetts Amherst

Abstract: Buildings have a considerable impact on the environment, and it is crucial to consider environmental and energy performance in building design. Buildings account for about 40% of the global energy consumption and contribute to over 30% of the CO₂ emissions. A large proportion of this energy is used for meeting occupants' thermal comfort in buildings, followed by lighting. The building facade forms a barrier between the exterior and interior environments; therefore, it has a crucial role in improving energy efficiency and building performance.

In this regard, decisionmakers are required to establish an optimal solution, considering multi-objective problems that are usually competitive and nonlinear, such as energy consumption, financial costs, environmental performance, occupant comfort, etc. Sustainable building design requires considerations of many design variables and multiple, often conflicting objectives, such as the initial construction cost, energy cost, energy consumption, and occupant satisfaction. One approach to address these issues is the use of building performance simulations and optimization methods.

This research presents a novel method for improving building facade performance, taking into consideration occupant comfort, energy consumption and energy costs. The research discusses development of a framework, which is based on multi-objective optimization and uses a Genetic Algorithm (GA) and machine learning in combination with building performance simulations. The framework utilizes the EnergyPlus simulation engine and custom scripts using Python programming to implement optimization algorithm analysis and decision support. The framework is automated in all steps: generating design scenarios, sending scenarios to the simulator, collecting the specific output, and decision making in optimization phase. So, the framework enhances the process of performance-based facade design, couples simulation and optimization packages, and provides a flexible and fast supplement in the facade design process by rapid generation of design alternatives.

The study describes the components and functionality of this framework in detail, as well as a two-step optimization technique, which is a new technique that combines GA and Machine Learning. This technique improves the framework speed, performance, and stability of an artificial neural network (ANN) and reduces the sensitivity.

The case study for a test cell presents, illustrating how the framework is used to test a variety of design possibilities and validation of this framework, as well as its application for facade design in different climates.

Keywords: Performance-based facade design, simulation-based optimization, machine learning, minimum viable product

INTRODUCTION

The buildings and building construction sectors combined are responsible for 36% of global final energy consumption and nearly 40% of total direct and indirect CO₂ emissions (IEA 2019). Energy demand from buildings and building construction continues to rise, driven by improved access to energy in developing countries, greater ownership and use of energy-consuming devices, and rapid growth in global buildings' floor area, at nearly 3% per year (IEA 2019). A large proportion of this energy is used for meeting occupants' thermal comfort in buildings, followed by lighting. The building facade forms a barrier between the exterior and interior environments, and has a crucial role in

improving energy efficiency and building performance. Therefore, this research focuses on performance-based facade design, appropriate simulation and optimization tools, and methods for design analysis and support.

Building performance simulation (BPS) provides relevant design information by indicating potential (quantifiable) directions for design solutions. BPS tools and applications facilitate the process of design decision-making by providing quantifiable data about building performance. BPS tools are an integral part of the design process for energy efficient and high-performance buildings, since they help in investigating design options and assess the environmental and energy

impacts of design decisions (Attia 2013). The important aspect is that simulation does not generate design solutions, instead, it supports designers by providing feedback on performance results of design scenarios.

Optimization is a method for finding a best scenario with highest achievable performance under certain constraints and variables. There are different methods for optimization, requiring use of computational simulation to achieve optimal solution, or sometimes requiring analysis or experimental methods to optimize building performance without performing mathematical optimization. In the BPS context, however, the term optimization generally indicates an automated process that is entirely based on numerical simulation and mathematical optimization (Nguyen 2014). Integrating BPS and optimization methods can form a process for selecting optimal solutions from a set of available alternatives for a given design problem, according to a set of performance criteria.

This paper focuses on developing a new framework for performance-based facade design. The framework considers energy consumption, occupant comfort, and energy cost optimality, and implements BPS and relevant optimization methods for performance-based facade design. The components and development of the framework are discussed in detail.

METHODOLOGY

The new framework for performance-based design approach, aiming to minimize building energy consumption and energy cost, while considering occupants' comfort level, was developed as part of this research. This is a modular framework, consisting of independent scripts that represent modules, steps, and functions of application under test. The modules are used in a hierarchical fashion to apply the framework, consisting of five steps:

1. Defining goals, performance criteria, facade design variables, and their properties, acceptable ranges for high-performance facade design.
2. Generating the database that includes all possible design scenarios based on the variables with permutation in Python and selected outputs after simulation in EnergyPlus. This is module 1.
3. Coupling Python script with simulation engine (EnergyPlus) to automatically perform simulations for scenarios from database (measurements methods) to quantify variables and generate the needed outputs. This is module 2.
4. Optimization phase by implementing Python script, genetic algorithm (GA) and Batch Normalization to evaluate outputs and find the optimal scenarios. This is module 3.

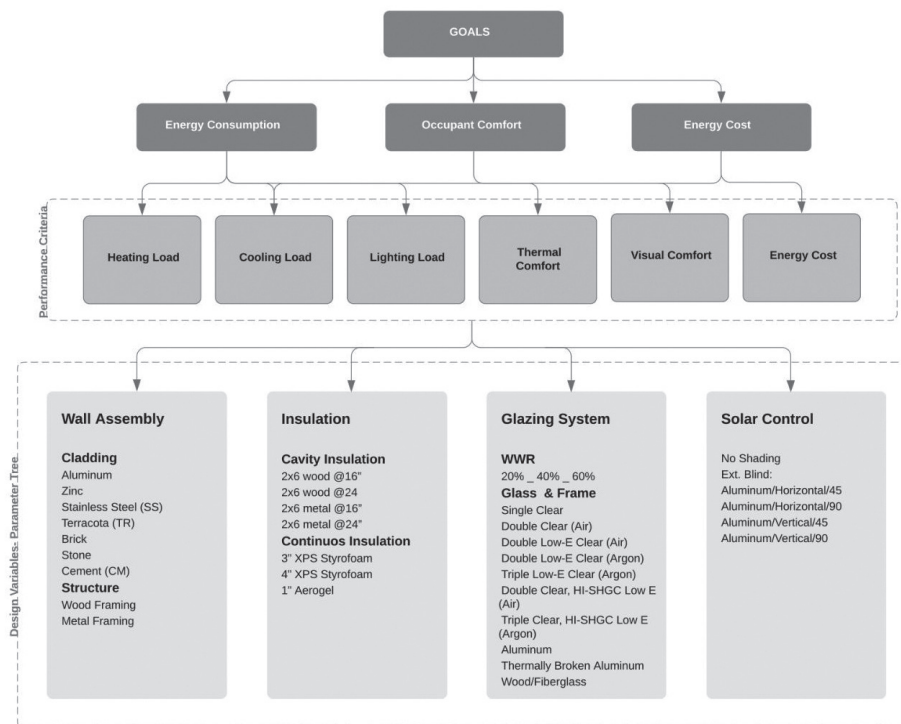


Figure 1: Conceptual diagram, showing components of the framework. (Author 2019)

5. Developing a front-end for user to test the framework and collect the data for next step, which is implementing deep learning after collecting enough data.

The next sections discuss the model development, then components of the framework and its implementation in detail will be illustrated.

Step 1: Defining Optimization Objectives, Performance Criteria and Facade Variables

Figure 1 shows the components of the framework. Performance-based facade design requires a holistic approach, considering performance indicators, such as energy performance and human comfort. These performance requirements (variables) must be quantified. The goals (optimization objectives) for this framework are to aid the design decision making process, where energy consumption and cost are minimized, and occupant comfort (thermal and visual) is maximized. The energy requirements for heating, cooling, and lighting of buildings are strongly driven by the performance of the facade, especially the glazing. The objectives for reducing energy consumption are to reduce heating, cooling, and lighting loads. Performance requirements (variables) to meet this objective are window to wall ratio (WWR), wall assembly, insulation, solar control, and glazing system. Performance-based facade design objectives that are related to human factors and contribute to occupant comfort and satisfaction in buildings include thermal comfort and visual comfort. The variables that relate to facade design include air temperature, mean radiant temperature, air movement, relative humidity, clothing layers and activity levels. The Predictive Mean Vote (PMV) suggested by Fanger (1970) predicts the effects of these six factors on thermal comfort. Predicted Percentage of Dissatisfied (PPD) persons predicts the percentage of people who would feel discomfort with certain thermal conditions. This research investigates how objectives are treated, what approach is more desirable and how to deal with constrained problems.

Step 2: Creating the Database (MYSQL)

After setting variables and parameters for facade design, all possible scenarios are generated using Python programming. With the permutation in Python script, design scenarios are generated and added to the database with a specific scenario ID. In this study, we have 38,400 scenarios to investigate for the test cell, described in the next section. After running simulation in EnergyPlus, all outputs in Step 3 are populated in this database with identical scenario ID. EnergyPlus provides a wide range of outputs, but, for this purpose, the following results are obtained:

- Cooling, heating, and lighting loads, Energy Use Intensity (EUI) for electricity and gas, PMV and PPD, and total energy costs for electricity and gas.
- Module 1 is responsible for generating all scenarios with defined variable and populating these scenarios in the database.
- Module 2 is responsible for automatically sending these scenarios to the simulation engine and for populating the selected outputs in the database.
- Data Flow Diagram (DFD) in figure 2 shows the overview of the framework system that represents the flow of data through this process.

The database manages all scenarios' inputs and outputs and is MYSQL, which is an open source relational database management system (RDBMS) that uses Structured Query Language (SQL) for adding, accessing and managing content in the database. The advantages of this type of database for the purpose of this research is the quick processing time, proven reliability, open source, ease and flexibility of use.

Step 3: Coupling Python scripts with Simulation Engine (EnergyPlus)

EnergyPlus 8.5 is used in this research as an energy modeling engine. EnergyPlus has been chosen as a BPS tool for two main reasons: (a) this program allows reliable modeling of both building and HVAC systems, and (b) it works with text-based inputs and

System Range	Heating temperatures set point: upper & lower band	Cooling temperatures set point: upper & lower band 73.5-80.5 °F (23-27 °C)	Relative humidity set point: upper band 60 %RH lower band 30 %RH
Occupant Comfort Range	PMV range: -0.5 to +0.5	10% PPD (Predicted Percentage of Dissatisfied)	
Fixed Parameters	Type: Medium office Floor area: 1600 ft ² Floor U-value: 0.10 Btu/ h ft ² F Zones program: Open office	Operating hours for UDI analysis: 9 AM-5 PM Num. of people per area	Equipment load per area Infiltration rate per area

Table 1: List of fixed parameters

outputs, and these facilitate the interaction with Python scripts. EnergyPlus can investigate discussed variables as inputs and simulate envelope related outputs in the study. Thermal comfort is calculated based on PMV and PPD. The formulas for both PMV and PPD are built into EnergyPlus and their values can be obtained directly from the simulation output file.

Initial simulation test cell considered a single office space (40'x40'x10'), located in Atlanta, Georgia. The south-facing facade was used to develop different design scenarios, varying WWR, materials, glazing system, and shading control. Defining related parameters as inputs and setting data needed for outputs are the primary method for connecting design scenarios in the database with the simulation engine. Python script works as an interface to call scenarios from the database and to send them to the simulator. Each parameter must identify a well-defined relation with discussed variables, which reveals facade behavior in relation to performance aspects being analyzed.

Step 4: Optimization Phase by Implementing GA and Machine learning

In building optimization studies using GA, the computational time is generally reduced by two methods. First, is the use of a very simplified model instead of complete simulation. This simplification can cause inaccurate modeling of the building. The other method is selecting a very small size for GA populations or a relatively small number of generations. One efficient solution to reduce the computational time associated with GA algorithm is use of machine learning techniques to reduce time and increase the accuracy of the results. The machine learning used in this research

is a combination of batch normalization, which is an Artificial Neural Network (ANN) technique, and flood fill algorithm. ANNs are effective methods that imitate the complex relationship of the network to solve multi objectives and non-linear problems. ANNs resemble the biological neural system, composed of layers of parallel neurons and weighted links. They learn the relationship between the input and output variables by studying previously recorded data. The layer that produces the network output are usually called the output layer, and all other layers are called hidden layers.

The optimization method in this study is a combination of GA and ANN, which is a machine learning technique. The GA in combination with flood fill algorithm and batch normalization creates a new technique to find a relation between the outputs, to assign weights, and dynamically adjust the target position to find optimal scenarios.

A batch normalization technique is used for the first phase of optimization. This is a technique for improving speed, performance, and stability of artificial neural network (ANN) by adjusting and scaling the activations. The batch normalization was introduced in 2015 by Ioffe and Szegedy. The intention behind batch normalization is to optimize network training. Several benefits of this methods are: faster training, higher learning rates, reduced sensitivity, and easier methods to initialize and produce better results (Hinton 2012). This technique, combined with a flood field algorithm, facilitates the optimization by sorting the highest indicators and decides which scenarios must be simulated.

The flood fill algorithm takes three parameters: start node, target, and replacement, and determines the

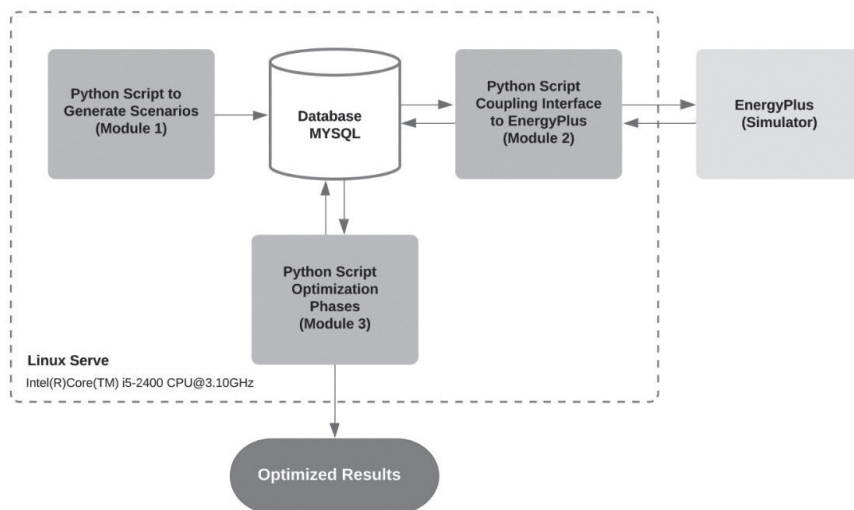


Figure 2: Data Flow Diagram (DFD) of the framework. (Author 2019)

area connected to our target. This algorithm facilitates the optimization by sorting the highest indicators and decides which scenarios must be simulated based on the specific scenario ID. Using this algorithm decreases the process time, because it is not necessary to simulate all scenarios—rather, only scenarios that are closer to the target. The comparison is based on the assigned indicator value. In a dynamic system, it is necessary to scale indicators to represent the impact of the indicators so as to configure following tasks and converge the results to the goal based on these scores. Figure 3 shows a sample for scoring total EUI electricity, EUI gas, PMV and energy cost indicators. These indicators work as fitness functions in genetic algorithms, which is a particular type of objective function to summarize and guide the simulations towards optimal design solutions. These indicators or fitness functions must correlate closely to the goals and must be computed quickly, because it needs to be iterated many times in order to produce usable results.

The initial population is generated randomly, based on the range of possible design scenarios. It is sent to the simulator to run the initial calculations, and then results are returned to the database to compare with the goals and standards. Then, design scenarios that have results closer to the goals are kept, and others are removed. In this framework, the goal is summation of three indicators, for energy consumption, comfort, and cost. The indicators are dynamically updated based on the range of results. The top left chart in figure 3 shows an example, where indicators from 6 to -3 are used for the initial test cell energy consumption results. Occasionally, the solutions may be “seeded” in areas where optimal solutions are likely to be found. Individual solutions are selected through a fitness-based process, where fitter solutions (as measured by a fitness function) are typically more likely to be selected. This method accelerates the simulation process and the results give us clusters of optimized scenarios for analysis in next phase of optimization. Figures 4 and 5 show how the optimization algorithm selects and sorts the fitted results for this framework.

Figure 4 shows the results before applying optimization for processing 2,061 scenarios and figure 5 shows the result of 18,103 scenarios with assigning the first step of optimization. In this case, we have 1,627 scenarios that scored 20 and more than 20 (1,591 scenarios at 20 and 36 more than 20). Using this process decreases the processing time, because it is not necessary to simulate all scenarios—rather, only scenarios that are closer to the target. After running all scenarios (38400 ID) and applying a batch normalization technique, 3,164 scenarios are selected. The next step focuses on comparison of results.

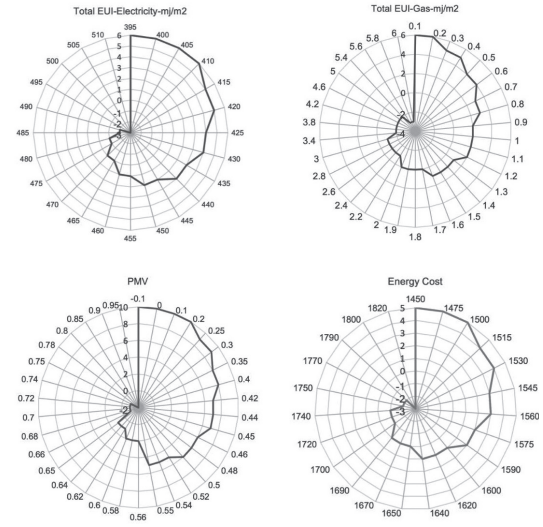


Figure 3: Total EUI-Electricity (MJ/m^2), EUI-Gas, PMV and Energy Cost indicator scores. (Author 2019)

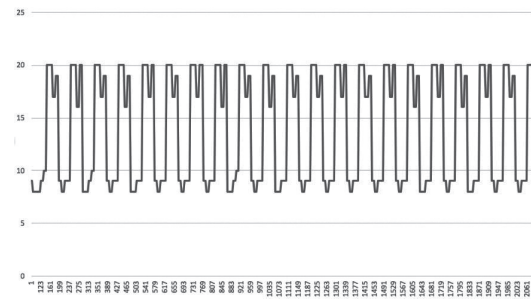


Figure 4: Total Indicators vs. Scenario IDs (for 2,061 scenarios). (Author 2019)

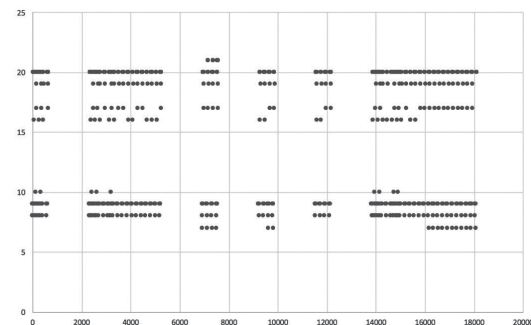


Figure 5: Total Indicators vs. Scenario IDs (for 18,103 scenarios). (Author 2019)

The next step of optimization is applying integrated correlation matrix clustering as a dropout technique, then comparing the results. This dropout is a regularization technique for reducing overfitting in neural networks by preventing complex co-adaptations on training data. Dropout refers to dropping out units

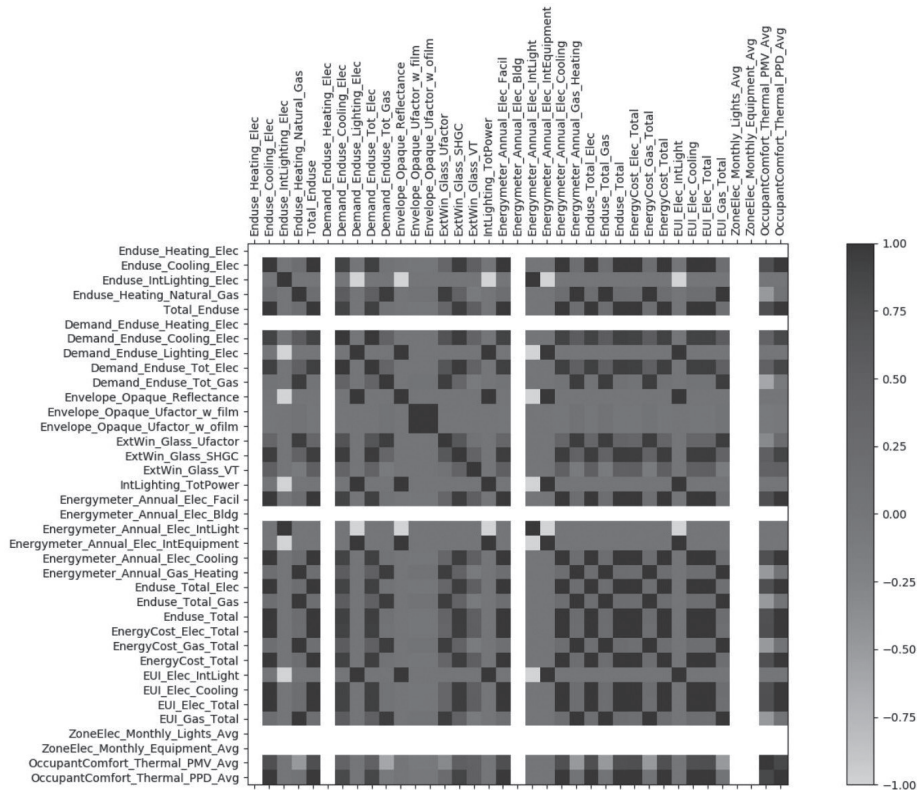


Figure 6: Correlation Matrix. (Author 2019)

(hidden or visible) in the neural network. In machine learning, correlation clustering provides a method for clustering a set of objects into an optimum number of clusters based on their similarity. So, in a correlation matrix, the relationship between the objects (variables) are known instead of the actual representations of the objects. Figure 6 shows the correlation matrix based on output data, integrated with optimization method to sort the results. Figures 7 and 8 show the final results of all scenarios with both techniques implemented. Figure 7 represents the first phase of optimization, and figure 8 shows the second phase after applying a correlation matrix and batch normalization. Results show that process time, performance, and accuracy are improved by using this method.

Step 5: Developing a front-end for user to test the framework and collect the data for next step which is implementing deep learning after collecting enough data.

This research studies simulation-based optimization methods and develops the framework for facade design that is automated and couples simulation engine with optimization algorithms. This framework can be used

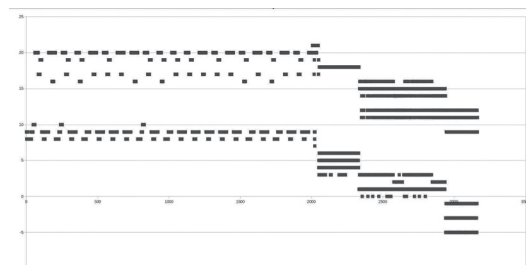


Figure 7: Results for all scenarios with applying batch normalization and flood field algorithm (Phase 1 optimization). (Author 2019)

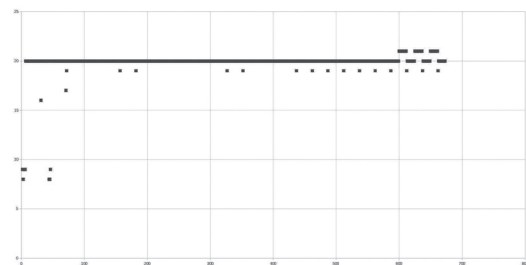


Figure 8: Results for all scenarios with applying correlation matrix and cluster eliminating (Phase 2 optimization). (Author 2019)

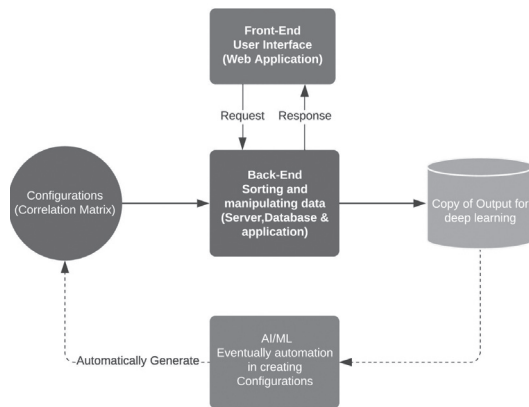


Figure 9: Data Flow Diagram L0 (Author 2019)

as a backend for web or mobile application (or any user interfaces) and, eventually after collecting enough data, the deep learning can be implemented to predict the configurations related to outputs.

Figure 10 represents the whole model development for this facade design tool. The focus of this model and framework is developing the MVP (Minimum Viable Product), which is the core feature to effectively deploy the product to the users. MVP can be part of the process directed toward making and selling this product to the users (Raddof 2014). It works as object in this iterative process of generation, presentation, data collection and analysis and learning. Creating MVP will allow collecting the maximum amount of validated learning data from users.

In this research, MVP is a web application product for users to test and collect data for a next development that needs big data for deep learning. This study mainly focuses on developing a framework as a back end and a simple front end for users' interface. Figure 9 shows the level 0 data flow diagram (DFD), which is known as a context diagram and shows a data system as whole and the way it interacts with external entities.

In order to develop the product based on this research, test the iteration, and collect the results and outputs, we need a user interface as the front-end that is connected to a developed backend. For this purpose, the MVC method is applied. MVC is a software and application design pattern used for developing interfaces and stands for Model, View, Controller as three separated interconnected elements. MVC is a lightweight highly testable framework as compared to traditional ASP.NET web forms. This method separates content from presentation and data processing from content. In other words, design pattern keeps the display and data separate to allow each to change without affecting the other and enable full control over the rendered HTML. So, the main advantages of the MVC

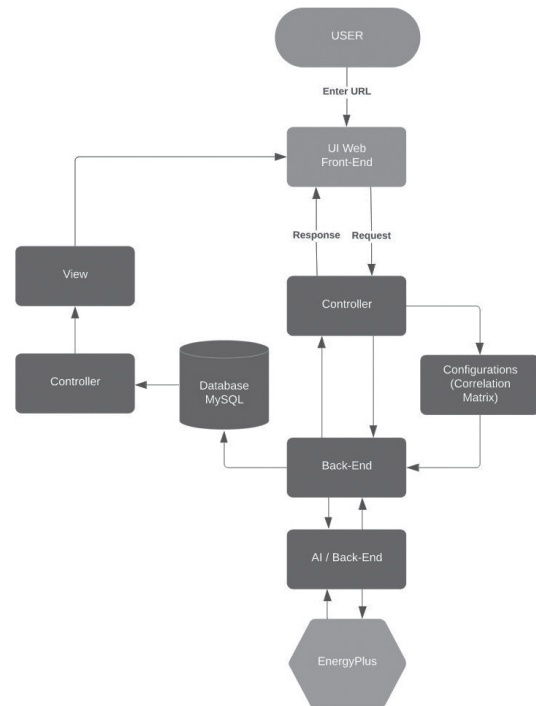


Figure 10: MVC flow chart (Author 2019)

method are providing clean separation of concern (SoC) and enabling test driven development (TDD).

Model represents the shape of data of the application. It is a central component that directly manages the data, logic, and rules of application and is independent of the user interface. It receives user input from the controller. View is a user interface that displays data, so users are able to modify it. View actually works as the front-end in this case. All result representations, such as charts, diagrams, tables, or any other specific forms can be displayed here. Controller handles the user request and renders the appropriate view with the model data as a response. In other words, it accepts inputs and data and converts them to commands for the model or view. Figure 10 illustrates MVC architecture and the flow of users' requests and responses in this case study. The interaction between the front end and back end with simulation engine and creating the configurations.

CONCLUSION AND FUTURE WORK

This research discussed the role of simulations and optimization in the design decision-making process. Then, a novel performance-based facade design framework was described, where different performance criteria and variables have been defined for achieving energy efficiency, occupant comfort, and cost optimality. The framework has been implemented by coupling

EnergyPlus as a simulation engine, and custom scripts using Python programming language. Then a user interface was developed with an MVC method to serve as a front end, in order to test and collect data. The research describes the components and functionality of this framework in detail, as well as the two-step optimization technique. A case study for a test cell was presented, illustrating how the framework is used to test a variety of design possibilities.

Future work will focus on the application for facade design in different climates and developing the user

interface. In addition to developing the user interface and web application, this product will be developed to accept any IDF files, the users will be able to choose their variable for optimization and then the rest of the process will be automated and results represented.

After releasing the open source application, other important developments for this research will be collecting the data for implementing deep learning on the data and outputs from different iterations, so as to enable the correlation matrix to generate automatically.

REFERENCES

- Aksamija, Ajla. 2013. *Sustainable Facades: Design Methods for High-Performance Building Envelopes*. New York: John Wiley & Sons.
- Attia, Shady, Mohamed Hamdy, William O'Brien, and Salvatore Carlucci. 2013. "Assessing Gaps and Needs for Integrating Building Performance Optimization Tools in Net Zero Energy Buildings Design." *Energy and Buildings* 60 (May): 110-124.
- Evins, Ralph. 2013. A Review of Computational Optimization Methods Applied to Sustainable Building Design. *Renewable and Sustainable Energy Reviews* 22 (June): 230-245.
- Evins, Ralph, Philip Pointer, and Stuart Burgess. 2012. "Multi-Objective Optimization of a Modular Building for Different Climate Types." In *First Building Simulation and Optimization Conference, Loughborough*, 173-180.
- Fanger, P.O. 1970. *Thermal Comfort. Analysis and Applications in Environmental Engineering*. Copenhagen: Danish Technical Press.
- Gosavi, Ab. 2015. *Simulation-Based Optimization*. Berlin: Springer.
- Hinton, Geoffrey E., Nitish Srivastava, Alex Krizhevsky, Ilya Sutskever, and Ruslan R. Salakhutdinov. 2012. "Improving Neural Networks by Preventing Co-Adaptation of Feature Detectors." arXiv preprint arXiv:1207.0580.
- Huang, Yu, and Jian-lei Niu. 2016. "Optimal Building Envelope Design Based on Simulated Performance: History, Current Status, and New Potentials." *Energy and Buildings* 117 (April): 387-398.
- Ioffe, Sergey, and Christian Szegedy. 2015. "Batch Normalization: Accelerating Deep Network Training by Reducing Internal Covariate Shift." arXiv preprint arXiv:1502.03167.
- Li, Xiwang, Jin Wen, and Er-Wei Bai. 2016. "Developing a Whole Building Cooling Energy Forecasting Model for On-Line Operation Optimization Using Proactive System Identification." *Applied Energy* 164 (February): 69-88.
- Machairas, Vasileios, Aris Tsangrassoulis, and Kleo Axarli. 2014. "Algorithms for Optimization of Building Design: A Review." *Renewable and Sustainable Energy Reviews* 31(March): 101-112.
- Nguyen, Anh-Tuan, Sigrid Reiter, and Philippe Rigo. 2014. "A Review on Simulation-Based Optimization Methods Applied to Building Performance Analysis." *Applied Energy* 113 (January): 1043-1058.
- Ostergård, Torben, Rasmus L. Jensen, and Steffen E. Maagaard. 2016. "Building Simulations Supporting Decision Making in Early Design—A Review." *Renewable and Sustainable Energy Reviews* 61 (August): 187-201.
- Ries, Eric. 2011. *The Lean Startup: How Today's Entrepreneurs Use Continuous Innovation to Create Radically Successful Businesses*. New York: Crown Books.
- Shi, Xing, Zhichao Tian, Wenqiang Chen, Binghui Si, and Xing Jin. 2016. "A Review on Building Energy Efficient Design Optimization from the Perspective of Architects." *Renewable and Sustainable Energy Reviews* 65 (November): 872-884.
- Wang, Haidong, and Zhiqiang John Zhai. 2016. "Advances in Building Simulation and Computational Techniques: A Review Between 1987 and 2014." *Energy and Buildings* 128 (September): 319-335.

SYSTEMS EVERYWHERE: On the Incorporation of the Vocabulary of Systems Sciences in Architectural Discourse During the Second Half of the 20th Century

Michael Moynihan
Cornell University

Abstract: Through a consideration of well-known architectural sources, this paper will take inventory of the divergent, contradictory, and sometimes productive ways architects and architectural writers came to rely on the language of systems sciences in the second half of the twentieth century.

For example, in K. Michael Hays' anthology *Architecture Theory Since 1968*, the word "system" appeared 640 times. Alberto Perez-Gomez used the word 51 times in his short introduction to Claude Perrault's *Ordonnance* to explain methodological changes occurring in seventeenth century France. There are other examples, of course: What Denise Scott Brown and Robert Venturi intended to learn from—far more than Las Vegas or Levittown—were "communication systems;" Jane Jacobs used complexity theory; Christopher Alexander said the city is a system not a tree; and even John Turner, an architect best known for self-build housing in Peru, used Ashby's Law of Requisite Variety (more commonly known as the first law of cybernetics) to argue against corporate and state power.

As Ludwig Von Bertalanffy said in his influential book *General Systems Theory*, "systems [were] everywhere." In this paper, I will untangle this complicated encounter between architecture and information sciences in two ways. First, I will show how systems metaphors have been used as a conceptual tool to define what has been called "architectural autonomy." This includes writers who created a systematic traceable relationship between organizational protocols of architectural form to define architecture as separate from culture, politics, or ideology. Second, I will show examples of how systems have been used as an operative tool for the designer; specifically, architects and city planners who used new sciences of control to solve large complex problems.

Keywords: Systems, autonomy, cybernetics, self-organization

In 1968, while outlining the foundations, applications, and development of a "General Systems Theory," Ludwig Von Bertalanffy observed that everywhere you look people are talking about systems. "If someone were to analyze current notion and fashionable catchwords," Bertalanffy says, "systems" would be high on the list (Bertalanffy 1969). Although successful in displaying the pragmatic potential of Systems Theory as a tool to unite research from diverse disciplines, unforeseen, even in Bertalanffy's introduction titled, "Systems Everywhere," was the important role systems theory would play in fields such as French Structuralism, Functionalist Sociology, Modernization Theory, Geography, Anarchism, and Architecture.¹ Because the expansion of architectural theory in the 1960s and 1970s shared the same conceptual stage as the ascendancy of systems thinking and theory, this final omission of architecture would surprise anyone who has read architectural scholarship in the past half-century, where it seems too, systems are everywhere.

Through a consideration of well-known architectural sources, this paper will take inventory of the divergent, contradictory and sometimes productive

ways architects and architectural writers came to rely on the language of systems sciences in the second half of the twentieth century.

For example, when Alberto Perez-Gomez, a historian trained in the 1960s, was reading Claude Perrault, an architect writing in seventeenth century France, what he found were systems (Perez-Gomez 1983).² In the most recent translation of Perrault's *Ordonnance for the Five Kinds of Columns After the Method of the Ancients*, a book where Perrault never used the word system (*systematique* or *systeme*), Alberto-Gomez relied on the word fifty-one times in the short introduction to explain the methodological changes he said were occurring in the period (Perez-Gomez 1993). There are other examples, of course: in the same year, what Denise Scott Brown and Robert Venturi intended to learn from—far more than Las Vegas or Levittown—were "communication systems" (Venturi and Brown 1977);³ in K. Michael Hays' anthology *Architecture Theory Since 1968* the word system appeared roughly the same amount of times (640) as the word building and the word design (Hays 1998); and even John Turner, an architect best known for self-build

housing in Peru, used Ashby's Law of Requisite Variety (more commonly known as the first law of cybernetics) to argue against corporate and state power (Turner 1978).⁴

Each of these examples is part of a significant transformation in the language used to describe the built environment in the 1960s. In some cases, this could be described generally as a move from organic metaphors to systems metaphors. This is apparent in an example like Kenzo Tange's Tokyo Bay Project, which was introduced using biological metaphors such as 'cell' and 'metabolism' in a publication presented at the World Design Conference in Tokyo of 1960 and later in the decade was reconceptualized as a 'structural approach', involving some "Systems Theory" (Colquhoun 2002, 238).⁵ In Christopher Alexander's *A City is not a Tree*, this shift is explicitly argued when he says "the system" should replace organic metaphors because of its ability to allow for new forms of mathematical rationality (Alexander 1966).⁶

The examples included above, and many like them, often say more about moods and trends in academic culture than they do about strict methodological change. Take, for example, the use of Complexity Theory by both Robert Venturi and Jane Jacobs.⁷ Although these are two very different sources, both use the idea of complexity rhetorically rather than methodologically to address some of the perceived naivetes of what each author called "orthodox modernism"; in the former to understand complex, organized wholes, and in the latter, community self-organization (Venturi 1966; Jacobs 1962).

Of course, not everyone uses the vocabulary of systems or systems metaphors. In some cases, even the language of historians commenting on technological changes in the late 1960s and early 1970s is inconsistent; this includes two historians who never directly address systems theory, Kenneth Frampton and, more surprisingly, Reyner Banham (Banham 1999; Frampton 1985).⁸ In a recently published collection of essays spanning the 1960s and 1970s, titled, *A Critic Writes*, Banham—despite acting as a hype man for the self-regulatory cities and cybernetic meadows of Archigram and conceiving of Los Angeles as a series of interconnected Ecologies—only uses the word system in terms of a collection of related parts such as a "building system" or "glazing system", or in the case of transportation networks such as a system of highways.⁹ Frampton never mentions systems in a chapter subtitled, "International Theory and Practice Since 1962" about Cedric Price, Archigram, Buckminster Fuller, Constant, Yona Friedman, and Kenzo Tange—all architects with some relationship to systems science, user-participatory systems, self-organization, and feedback.¹⁰ This is in contrast to the historian Allan

Colquhoun, for example, who while writing a survey on the same period—including the same architects—not only discusses systems, cybernetics, and self-regulation but cites Bertalanffy and titles the section of the book, "Systems Theory" (Colquhoun 2002).¹¹ Even Emil Kaufman, who in 1943 defined modern architecture as "the new architectural system," was relying on the earliest common use of the word system in architecture which was through proportional systems or to define specific codified part-to-whole arrangements (Kaufmann 1943). Modern Architecture, for Kaufman, was a new system precisely because it was no longer a system at all; instead, it was seen as free from previous proportional systems such as the "Baroque System."

By the end of the twentieth century, this appropriation of systems vocabulary is significant enough that it becomes difficult, at times, to connect the things architects say to their original meaning in scientific jargon. In Cary Wolfe's *What is Posthumanism*—a book written 40 years after Bertalanffy's *General System Theory* but taught in many of the same syllabi—an entire chapter is devoted to the systems language used by architects (Wolfe 2010). In a single competition for a park in Toronto in 2000, Wolfe finds the phrases "emergence," "self-organizing," "circuit," "flow ecologies," "sustaining and multiplying complexity over time," "open phasing," "function-based circuit systems," "Webs," and "Grammar strings." "What these terms do," and more specifically what the architects employing these terms do, Wolfe suggests, "is take for granted the conceptual apparatus of systems theory" (Wolfe 2010, 205). In a proposal by the architecture firm, *Corner and Allen*, called *Emergent Ecologies*, the architects say, "our approach is an emergent and dynamic organizational matrix for the life of the site to unfold," in which the "landscape of circuits and flows simply guides or steers the always emergent process of matter and information." Two other proposals analyzed by Wolfe include one by *Brown and Storey* and another by *Foreign Office Architects*. The former is called *Emergent Landscapes* and involves "an evolving landscape of stages, phases of order and stability... evolving relationships, momentum and self-organizing structures," and the latter, a "new synthetic landscape faced with complexity" where the architects "respond by sustaining and multiplying that complexity over time."

Because the language of systems have been incorporated into architecture in such a variety of ways, it would be impossible in a single paper to untangle all of the divergent strands, such as: a way to better understand the interrelationship between actor and observer,¹² the material distinction between inside and outside,¹³ the relationship between communication and meaning,¹⁴ and, generally, as a linguistic placeholder

for the common architectural question of order.¹⁵ Instead, in this paper, I will show two ways architects and architectural writers have used systems or the language of systems to define specific goals in their work. First, I will show how systems metaphors have been used as a conceptual tool to define what has been called “architectural autonomy.” In this section, I will show examples of architects and architectural critics who have borrowed systems language from sociologists to define the ‘formal language’ or ‘internal protocols’ of architecture as a closed system, or more simply, as something separate from culture, politics and ideology. Second, I will show examples of how systems have been used as an operative tool for the designer to accomplish specific goals. On one hand, this type of systems approach gave architects a new vocabulary to critique top down modernist city planning strategies, such as those outlined in the Athens Charter, and on the other, allowed architects and city planners using new sciences of control to solve large complex problems, such as cost efficiency and national development. Using ideas of self-regulation, feedback, user participation, self-organization, steering, and homeostasis many architects expressed the ability of systems sciences, most specifically cybernetics, to design architecture capable of performing clear and understandable objectives; from the organization of cubicles to the settlement of cities in outer space.

1. SYSTEM AS A CONCEPTUAL MODEL TO DEFINE ARCHITECTURAL AUTONOMY

In Cary Wolfe’s chapter on architecture in her book, *What is Posthumanism?*, the intent is to expand on what she calls the “central innovation of systems theory,” that is, “replacing the familiar ontological dualities of the philosophical tradition with the functional distinction between system and environment” (Wolfe 2010, 206). In this particular chapter, Wolfe uses architectural examples to discuss the ontological duality of nature/culture—something systems theory has been used for by posthumanist thinkers to shift questions of culture away from natural or biological distinctions.¹⁶ This nature/culture question has also been a recent trend in architectural scholarship.¹⁷ However, historically in architectural discourse the use of the functional distinction between system and environment has been used to define architectural form (system) as something separate from categories such as culture, politics, ideology, etc. (environment).

This functional distinction discussed by Wolfe comes from Chilean Biologists Humberto Maturana and Francisco Varela who invented the term ‘Autopoiesis’ to study the effects of environmental phenomena on organisms (Varela and Maturana 1974).¹⁸ For these two

scientists, “autopoietic systems” are biological systems that define and maintain their own material boundaries external to the environment, and although autonomous systems, they are still understood as structurally linked to non-observable environmental effects. This idea, once stripped of its conceptual rigor, or pragmatic purpose for biological study, is intuitively understood by some architects and architectural theorists as a tool to metaphorically define disciplinary boundaries.

The term Autopoiesis found its way into architectural discourse through the writing of Niklas Luhmann (Luhmann 2011).¹⁹ While looking for “a general theory of society,” Luhmann published a series of lectures called “Social Systems.” Taking from the 1960s functionalist sociologist Talcott Parsons—the first person to define ‘the social’ as a system of its own—Luhmann incorporated this idea of Autopoiesis and used it to distinguish between ‘the social’ and other phenomena (biological, psychological, etc.) which are not strictly observable but are still structurally coupled with “the social.” Within the Social System, Luhmann defines many other autopoietic subsystems, each containing their own various mechanisms and protocols to define and maintain their boundaries, such as law, economy, politics, art (in this case, including architecture), etc..

In architecture, as shown by Cary Wolfe, the use of this language is sometimes meaningless rhetorical accouterment; however, for some, such as Patrick Schumacher, the term autopoiesis has been central to his attempts to establish a unified theory of architectural autonomy (Schumacher 2011).²⁰ What is actually meant by Schumacher’s use of autopoiesis is not explicit in his work. Instead it appears to be used as a theoretical apparatus to narrow the discussion of architecture to form alone. The specific purpose of ignoring certain external factors, understood as outside of architecture’s discipline, is most clear in his recent public comments about eliminating social housing, privatizing all public spaces, developing most of Hyde Park, and perhaps even in his direct affiliation with the death of nearly 1000 migrant workers in preparations for his firm’s 2022 World Cup Stadium in Qatar. Instead of drawing on aspects of systems theory to challenge familiar ontological dualities which has been seen in the work of posthumanist theory, Schumacher takes the functional distinction between system and environment literally as a way to promote right wing rhetoric.

What is interesting about Schumacher, for the sake of this discussion, is that his work is drawing on a desire to express the parts of a building as a single self-contained whole. This desire has been expressed using various scientific metaphors throughout architectural history, which he draws upon often conflating and synthesizing distinct architectural arguments. As a

result of this ahistorical approach, there has been significant criticism extended to Schumacher, such as by Antoine Picon, who notes his inability to distinguish this theory from previous models of architectural autonomy such as those presented by K. Michael Hays in the 1980s and 90s (Picon 2011).²¹

This inability of Schumacher to distinguish his own architectural theory from authors like K. Michael Hays and others stems from his reliance on similar intellectual influences. The theoretical legitimacy of architectural autonomy is often derived from structural theorists, whose work is part of a systems approach. This has included “deep structure” from Noam Chomsky, relative autonomy and the ideological state apparatus from Louis Althusser, and the theory of assemblages from Gilles Deleuze and Felix Guattari.²² Although distinct in their own right, once these conceptual models are brought into the narrow metaphor of architectural autonomy, they are all, in effect, exactly the same.

K. Michael Hays, for example, was relying on the intellectual history of systems theory when he said that architecture should be understood through its internal protocols, that is, “how its parts have been put together, how it is a wholly integrated and equilibrated system that can be understood without external references, and as important, how it may be reused, how its constituent parts and processes may be recombined” (Hays 1984, 16). The use of the idea of a homeostatic “equilibrated system” becomes a tool to discuss these internal concerns as distinct but somehow structurally coupled with economic, political, cultural, and technological processes which are responsible for the various historical transformations in architecture.²³ An example of this type of mediation—and one that Hays cites in his Introduction to *The Oppositions Reader* when trying to work out the relationship between the “historical determinism” of Manfredo Tafuri and the “formal autonomy” of Colin Rowe—is Diana Agrest’s 1974 paper “Design vs. Non-Design.” In this definition of architectural autonomy, Agrest says:

Design, considered as both a practice and a product, is in effect a closed system—not only in relation to culture as a whole, but also in relation to other cultural systems such as literature, film, painting, philosophy, physics, geometry, etc. Properly defined, it is reductive, condensing and crystallizing general cultural notions within its own distinct parameters. Within the limits of this system, however, design constitutes a set of practices—architecture, urban design, and industrial design—unified with respect to certain normative theories. That is, it possesses specific characteristics that distinguish it from all other cultural practices and that establish a boundary between what is design and what is not. (Agrest in Hays 1998, 198)²⁴

Often when the language of systems is imported into architecture as a tool to discuss, in general, architecture’s relationship to culture, it comes with the

intent to maintain some formal discourse—something traditionally thought to be unique only to the discipline of architecture and that discipline’s primary meta-critical language for resistance against such cultural forces.²⁵ In other words, if the ‘formal language’ is not a closed system, architecture’s ability to critique culture is suppressed by a belief that culture is embedded within architectural form, and the architect’s work is presumed to be nothing but a representation of the culture that produced it. To achieve this mediation between culture and architecture, Agrest is focused on “the discursive specificity of architectural codes which are nevertheless permeable to other cultural codes.” This Agrest takes from Louis Althusser’s use of a system model to define relative autonomy.²⁶ In Hays’ words, these systems models “show the work of architecture as having some autonomous force with which it could also be seen as negating, distorting, repressing, compensating for, and even producing, as well as reproducing, [its social ground or] context” (Hays 1998, X).

2. SYSTEMS AS A CONCEPTUAL MODEL FOR FLEXIBLE DESIGN

In 1963, Margaret Mead, Marshall McLuhan, Buckminster Fuller, and ten others were invited onto a boat circling the Greek Islands to have a conversation about “the evolution of human settlements.”²⁷ Constantinos Doxiadis, a planner and architect who had designed cities in collaboration with the Ford Foundation and the United States all over the decolonizing world, invited these prominent cyberneticians and information technology theorists to reenact the famous boat ride on the S.S. *Patris* between Marseille and Athens, where the *Athens Charter* was originally signed. On the final day of the trip, in a Greek amphitheater in Delos, the group signed a document called the *Delos Declaration* in an attempt to bring modern city planning into the information age.²⁸ According to Mark Wigley in his account of this event, *The Delos Declaration* marks a shift in the 1960s to thinking about architectural design through networks rather than objects, or in Wigley’s words, “The architect is seen as the networked animal that networks networks” (Wigley 2001, 94).

While the examples in the previous section of “closed systems” and “autopoiesis” were used primarily to analyze architecture, very often, and as this meeting in the Greek Isles attests, systems sciences—in particular, cybernetics—were thought to be the next great tool for architectural design. Often these resulted in a pursuit of more flexibility. Experiments with trying to make cybernetics a viable tool for design took on two distinct but overlapping forms in the 1960s and 1970s. The first was to address how changes in technology could allow the individual more flexible and adaptive

living environments, and the second was to create more economically efficient modes of production. Early examples of these range in scale from Robert Probst's work with The Herman Miller Furniture Company to cities that are designed to cover the globe, such as Constant's *New Babylon*.²⁹

In the *Delos Declaration*, and in many examples throughout the 1960s, these attempts at flexibility were often used to challenge the supposed homogenizing effects of modernist top down planning practices, which were said to be unable to foster 'community.' As early as 1953, at the ninth meeting of the *Congrès Internationaux d'Architecture Moderne* (CIAM), Alison and Peter Smithson and Aldo van Eyck used 'systems' to challenge the four categories found in the *Athens Charter*: Dwelling, Work, Recreation, and Transportation. These functionalist categories were replaced by: House, Street, District, and City (Frampton 1985).³⁰ In these new categories, the house is not understood as a building but a unit of analysis and the street, particularly in the Smithson's Golden Lane scheme, is named the system which maintains and facilitates this base 'family unit.'³¹ According to Allan Colquhoun in the 1950s and 1960s, "A 'cybernetic', self-regulating element was introduced into the way cities and large buildings were conceptualized." This is true in the Smithson's work, which Colquhoun says, "Instead of users being presented with predetermined spatial patterns, they were now—at least in theory—offered the means to alter their own micro-environment and decide their own patterns of behavior" (Colquhoun 2002, 234). While this idea is only implied by early examples of Dutch Structuralism and the Metabolists, Colquhoun says, it becomes "the central issue" in the work of Cedric Price, Yona Friedman, Michael Webb, and Constant.³²

In contrast to architects and designers of the self-regulating megastructures and cybernetic cities, throughout the 1960s there were many efforts to define how new systems approaches could be used to make the production of architecture cheaper and more efficient. In 1967, the magazine *Progressive Architecture* devoted an entire issue, titled "Performance Design," to the organization of office space and the "science" of design. In a direct response to this issue but also to consolidate many of the ideas emerging in systems thinking in the 1960s, James Boyce wrote an essay called "What is the systems approach?" (Boyce, 2007).³³ Here he defined explicitly three ways systems sciences could be used by architects: sequential design processes, cyclic-design processes, and evolutionary design processes. A year later, Benjamin Handler wrote a book called *Systems Approach to Architecture* where he was attempting to solve, once and for all, the complexity of decision

making in architectural projects by outlining every measurable part of a building's life; from "auditory comfort" and "illumination levels" to "blood pressure" and "discrimination" (Handler 1970). In far greater schematic detail than Boyce, Handler systematically breaks the design process and "life of the building" into manageable architectural subsystems with understandable inputs and calculatable outputs, based on performance objectives in the design program.

In 1973, The United Nations Department of Economic and Social Affairs looked to implement many of these findings in a book called *Integration of Housing into National Development Plans: A Systems Approach*. Building on the ideas published by Handler, the authors of the report outlined "an econometric simulation model primarily oriented to the situation of the developing countries." This model simulates the impact on the economy, family income, the rate of rural-urban migration, the level of infant mortality, overcrowding, educational levels, and in particular, the demographic and social aspects of housing.

For the Smithson's and those using cybernetics mentioned by Colquhoun, individualized, flexible housing was thought the challenge to the supposed homogenizing modernist housing blocks. For the United Nations and transnational credit institutions, such as World Bank, individual housing was also a way to challenge large-scale modernist slab housing, which was seen as a poor investment for national economies and transnational credit intuitions because of the high capital-output ratio associated with construction. This is evident throughout the 1970s when several conferences and world congresses, such as the *World Congress of Architecture and National Development* held in Mexico City in 1978, looked to combine these new computationally driven economic housing strategies with architects' technological ambitions.

By the late 1970s, the word system was so malleable that it could serve as both a conceptual alternative to functionalist top-down modern city planning strategies and advance new economic models of 'development'. This malleability can be seen at the event in Mexico City, where, on one hand, architects from most Latin American countries accessed flows of international finance and took part in conversations with politicians, economists, and technocratic elites, and on the other, architects such as those associated with the Lima-based intellectual movement, *Agrupacion Espacio*, presented their critique of the *Athens Charter* named *La Carta de Machu Picchu* (Kahatt 2011).³⁴ Like the *Delos Declaration*, *La Carta de Machu Picchu* used the language of systems and self-organization, however, this was intended to comment on the inability of the *Athens Charter* to accommodate local specificity.

Given the divergent, ambiguous, and contradictory ways systems thinking has been incorporated into architecture, one question emerges: Why do architects and architectural writers so consistently rely on the vocabulary of systems and systems metaphors? According to Benjamin Handler, "The systems concept is implicit in the way in which architects think and work." He continues by saying, "a building is a system" that is "an interconnected complex of functionally related components designed to accomplish a particular objective" where "the whole is primary, the parts secondary" (Handler 1970, 21). It is probably true that the understanding of architecture described by Handler has allowed some architectural thinkers to easily conflate a historical language of part-to-whole with the analytical tool, 'systems'. While this seems reductive, perhaps this is exactly why Alberto Perez-Gomez

sees systems when Perrault questions Vitruvius and Schumacher sees systems when Alberti cites Cicero. Adrian Forty, in his book *Words and Buildings*, says the word "circulation" as an architectural metaphor taken from science, first by Charles Garnier and Viollet-le-Duc, may be related to this desire to express the parts of a building as a single self-contained whole (Forty 2000). Whether these types of linguistic conflation are occurring in the examples referred to in the paper is impossible to say. However, like other scientific metaphors, this reliance on the vocabulary of systems is often made as a claim of scientific legitimacy. Both cases brought up in the second half of this paper emerged in the postwar period when critiques of architectural modernism's supposed failure to fulfill its social promises shared the same conceptual stage as the advent of systems theory.

ENDNOTES

- 1 Bertalanffy notes the use of systems theory in Piaget and Levi-Strauss' in the updated 1973 preface. In sociology the two main sources in the 1960s are Talcott Parsons, *The Social System*, (Glencoe: Free Press, 1951) and Robert K. Merton, *Social Theory and Social Structure*, (Glencoe: Free Press, 1949). In the 1980s these are expanded upon by Niklas Luhmann, *Introduction to Systems Theory*, trans. Peter Gilgen, (Cambridge, UK ; Malden, MA: Polity, 2012). On the first page of Fernando Henrique Cardoso and Enzo Faletto's book, *Dependency and Underdevelopment in Latin America*, the authors note that in modernization theory, Talcott Parsons and Robert K. Merton "Have decisively influenced the formulation of the type of development analysis that 'argued that Latin American societies belong to structural type generally called 'traditional,' which is giving way to another type of society called 'modern.' Another, very different example of using a system model to challenge modernization theory is Immanuel Wallerstein, *The Modern World-System: Capitalist Agriculture and the Origins of the European World Economy in the Sixteenth Century*, (London: Academic Press, 1974). For the ways the language of 1960s anarchism was effected by the incorporation of cybernetics see: John Duda, "Cybernetics, Anarchism and Self-Organisation," *Anarchist Studies* 21.1 (London: Lawrence and Wishart, 2013). 52-72. John McEwan, 'Anarchism and the Cybernetics of Self-Organizing Systems'. *Anarchy* 31: (1963). 270-83. And Colin Ward, 'Anarchism as a Theory of Organisation'. *Anarchy*, 62: (1966) 97-109.
- 2 Alberto Perez-Gomez, *Architecture and the Crisis of Modern Science* (Cambridge: MIT Press, 1983). We are lead to believe authors of 17th century France were not using the word system (except for perhaps in one account where Alberto-Gomez says Blondel was reading Galileo), however, that all along architects were talking about systems and, because of this, something inherent to the methodology of practicing architects was changing, following Perez-Gomez: "Theory thus reduced to a self-referential system whose elements must be combined through mathematical logic must pretend that its values, and therefore its meaning, are derived from the system itself."
- 3 Robert Venturi, Denise Scott Brown, and Steven Izenour, *Learning from Las Vegas* (Cambridge: The MIT Press, 1977). This is made clear on the translucent dust jacket that came with the first edition, which gives alternative titles for the book to read: "Symbol in Space before Form in Space: Las Vegas as a communication system." And "System and Order on the Strip"
- 4 John Turner, "Housing in Three Dimensions: Terms of Reference for the Housing Question Revisited," *World Development* Vol 6 No. 9/10. (1978): 1134-1145. See W. R. Ashby, "Self-regulation and requisite variety", Chapter 11 of *Introduction to Cybernetics*, (New York: Wiley, 1956), reprinted in F. E. Emery (ed.), *Systems Thinking* (Harmondsworth: Penguin, 1969). "If stability (of a system) is to be attained, the variety of the controlling system must be at least as great as the variety of the system to be controlled." This, Turner used to argue that any society complex enough to support corporate organization would have a housing system far too complex to be managed by that corporate organization. p. 1141.
- 5 David B. Stewart, *The Making of a Modern Japanese Architecture, 1868 to the Present* (Tokyo and New York, 1987), 179-181. Quotation found in Alan Colquhoun, *Modern Architecture* (Oxford: Oxford UP, 2002), 238.
- 6 Christopher Alexander, "A City Is Not a Tree," *Design* (February 1966), 48; originally published in slightly different form in: *Architectural Forum* (April 1965), 58-62 and (May 1965): 58-61. See also: Andrew Shanken, "The Tree in the System: Shifting urban paradigms in Mid-Century London," *Perspecta*, Vol. 45, *Agency* (2012), 143-152.
- 7 Robert Venturi, *Complexity and Contradiction in Architecture* (NY: MOMA Press, 1966) and Jane Jacobs, *The Death and Life of Great American Cities* (NY: Vintage, 1992). One essay connects these two writers through the use of Complexity theory, see: Peter Laurence, "Contradictions and Complexities: Jane Jacob's and Robert Venturi's Complexity Theories" *Journal of Architectural Education*, Vol. 59, No. 3, (Feb., 2006), 49-60.

- 8 Reyner Banham, *Theory and Design in the First Machine Age* (Cambridge: The MIT Press, 1980) Reyner Banham, *A Critic Writes: Selected Essays by Reyner Banham* (California: U California Press, 1999) Reyner Banham, *Architecture of the Well-Tempered Environment* (Chicago: U Chicago P, 1984) Reyner Banham, *Megastructures: Urban Futures of the Recent Past* (London: Thames and Hudson, 1976). Kenneth Frampton, *Modern Architecture: a Critical History* (London: Thames and Hudson, 1985)
- 9 System of Highways comes from 1950s systems sciences as part of a decentralization brought on by the "Urban Dispersal movement." According to Reinhold Martin, "the organizational complex itself as seen through the medium of an emergent cybernetics and, in particular, through the application of redundant feedback loops to an urban context in which the city was understood as a primary cold war target. In this cybernetic sense, decentralization, or the dispersal of urban infrastructures into an increasingly horizontal network of communication and transportation lines, was an instrument not merely of civil defense against an external enemy, but of defense against an internal one: the disorder that was anticipated with the demise of centralized governmental and civil authority in the immediate aftermath of a nuclear strike. And so technocratic aesthetic research accelerated in the direction of ever more efficient mechanisms of self-regulation, self-organization. These in turn helped invent new kinds of cities, new kinds of architectures, and with them new "self," none of which could be said to possess the traditional spatial properties that divide inside from outside in any meaningful sense." For a more detailed discussion of "urban dispersal movement" and its relationship to post war architecture and city planning, See: Reinhold Martin. *Organizational Complex*. (Cambridge: MIT Press, 2005), 7. See also: National Interstate and Defense Highways Act of 1956." June 29, 1956; Enrolled Acts and Resolutions of Congress, 1789-1996; General Records of the United States Government; Record Group 11; National Archives.
- 10 Kenneth Frampton, *Modern Architecture: a Critical History* (London: Thames and Hudson, 1985), 280-313.
- 11 See: Alan Colquhoun, *Modern Architecture* (Oxford: Oxford UP, 2002). 235. See also: Hans Ulrich Obrist, Yona Friedman: *The Conversation Series* (Köln: Verlag der Buchhandlung Walther König, 2007).
- 12 See: Lily Woodruff. "The Groupe de Recherche d'Art Visuel against the Technocrats" *Art Journal*, Vol. 73, No. 3 (Fall 2014), pp. 18-37. Monica Amor, "From work to Frame, In between and Beyond: Lygia Clark and Helio Oiticica, 1959-1965," *Grey Room* 38 (winter 2010); 20-37. See also Joan Littlewood's reading of Brechtian Theatre in Theatre Workshop manifesto (c. 1930s) Joan Littlewood Archive, British Library. For accounts of epic theatre and Brecht more generally, see Sarah Bryant-Bertail, *Space and Time in Epic Theatre* (Rochester, NY: Camden House, 2000); Manfred Wekwerth, *Daring to Play: A Brecht Companion* (London: Routledge, 2011); and David Barnett: *Brecht in Practice: Theatre, Theory and Performance* (London: Methuen, 2015).
- 13 Lloyd Thomas, Katie, "Between the womb and the world: Building Matrixial relation in the NICU" from Peg Rawes, *Relational Architectural Ecologies: Architecture, Nature and subjectivity*, (New York: Routledge, 2013) 192-208. For a conflation of systems theory and emergence of inside/outside questions associated with architecture. At a larger scale see: William J. Mitchell, *Me++: The Cyborg Self and the Networked City* (Cambridge: The MIT Press, 2004), at the scale of building design, Greg Lynn, ed., *Folding in Architecture* (New York: John Wiley & Son, 2004); for a collection of writing associated with this trend See: Mario Carpo, ed., *AD Reader: The Digital Turn in Architecture 1992-2010* (Chichester: Wiley, 2012).
- 14 See: Peggy Deamer. "Structuring Surfaces: The Legacy of the Whites." *Perspecta*, Vol. 32, *Resurfacing Modernism* (2001). Because cybernetics is a science of communication, the relationship between meaning and communication has been a central feature in much of the work that looks at cybernetics, however, one way this has been transformed into an architectural theory is through the work of Peter Eisenman. It could be argued that his interpretation of Chomsky's concepts "deep structure" and "surface structure" in the 1960s was not to understand the social construction of language nor its mere phonetic form (surface structure), but instead to understand the specifics underlying the human being's universal ability to understand the relative organization and nonfigurative order of language. This idea helps Eisenman define his version of "architectural autonomy"; primarily because language is an imperceptible vehicle and further, its "deep structure" has no representational form. Or, as Peggy Deamer has described it: "language's seeming universality as a logic made it a meta-system, not an outside discipline." For a clear description of Eisenman's use of "deep structure." p. 94.
- 15 See Adrian Forty. "Order" in *Words and Buildings: A Vocabulary of Modern Architecture*. (London: Thames and Hudson, 2000). 240-249. This shift away from order has often been attributed rather reductively to architects' reading Foucault and Lefebvre, which according to the historian Adrian Forty made "it no longer possible to talk about 'order' innocently in architecture." Forty names the final paragraph of Foucault's "the Order of things" as an important genealogical strand for this type of thinking, and uses Bernard Tschumi as a positive example of attempting to side step the traditional ways modern architecture has entangled with capitalism and modern science. This discourse surrounding contemporary questions of order is so entrenched in systems language that by the 21st century even Adrian Forty—whose book *Words and Buildings* pays particularly close attention to the metaphors of science popping up in architecture—accidentally uses a systems metaphor in the concluding sentence in his chapter on order: "If architecture does not create 'order' he says, "there would be no need to have architecture at all...but if architecture is in the business of producing 'order', it is involved in something far bigger than it can possibly handle, the process by which experience is filtered, transformed and fed back to use in reduced form, all in the name of 'culture.'" p 249.
- 16 Others doing this include Donna Haraway, "Manifesto for Cyborgs: Science, Technology, and Socialist Feminism in the 1980s," *Socialist Review* 80 (1985): 65-108. In Wolfe's first chapter is about the similarities in the way Jacques Derrida and Niklas Luhmann—two authors architects have been excited to conflate—confront the question of difference; the former to challenge the logocentric philosophical tradition and the latter through the problem that systems seek autopoiesis. In posthumanism, these are important because they "refuse to locate meaning in the realm of the human or biological."
- 17 See: Peg Rawes, *Relational Architectural Ecologies: Architecture, Nature and Subjectivity*, (New York: Routledge, 2013). See also: Ariane Lourie Harrison. *Architectural Theories of the Environment*. (New York: Taylor & Francis Group, 2013). This book actually contains the chapter on architecture from Cary Wolfe's book.

- 18 F.F. Varela, H. R. Maturana, R. Uribe, "Autopoiesis: The Organization of Living Systems, its Characterization and a Model," *Biosystems* 5 (1974): 187-196. See also: Maturana, Humberto R, and Francisco J Varela. *The tree of knowledge: the biological roots of human understanding*. (Boston; Shambhala, 1992). See also: Wolfe, Cary, "In Search of Post-Humanist Theory: The Second-Order Cybernetics of Maturana and Varela," *Cultural Critique* 30 (1995): 33-70.
- 19 For a clear description of how Luhmann incorporates Autopoiesis, or what is called the 'Autopoiesis turn' in sociology see "Preface" in Niklas Luhmann. *Introduction to Systems Theory*. Polity Press, 2011.
- 20 Schumacher compares architecture to other historically produced subsystems discussed by Luhmann: "Luhmann discovers a series of important processes that determine these different systems within the era of modernity. The emerging market-orientation of the economy, the liberalization of the economy, is the pertinent way for the economy to become an autopoietic system. The political system has been evolving and succeeding through democratization, and only through democratization does it become a truly autopoietic, self-referentially closed system. The legal system found its autonomy and forward drive through positivism rather than natural law or God-given legal discourse. Art discovered its self-programming in romanticism. All of these mechanisms mean that these systems become autonomous and adaptive to each other. They become versatile, innovative, progressive, and ever-evolving. All these processes are established some-where between 1800 and 1900. My thesis here is that the concept of space, or the spatialization of architecture, is the equivalent of the democratization of the political system, the liberalization of the economy, etc." Of course, 'spatialization' or 'the concept of space' is not exclusive to architecture, in fact 'Autopoiesis' as understood by the biologists Varela and Maturana is both material and spatial. One could even ask, why, according to Schumacher, if space is the historically produced condition that allows for architecture's autonomy then why would 'second order systems' be an appropriate metaphor to conceptualize architecture, given that these conceptual models rely on terms, such as emergence and self-organization, which result in shifting questions from space to time? See: Patrick Schumacher, "Parametricism and the Autopoiesis of Architecture," *Log* 21 (March 2011), pp.63-79
- 21 Antoine Picon, "When Parametricism Tries to Reconnect with Vitruvius," *Log* 23 (2011): 53-57. See also: Eric Owen Moss, "Parametricism and Pied Piperism: Responding to Patrick Schumacher," *Log* 21, (2011), pp.81-87.
- 22 For a clear description of Eisenman's use of "deep structure" see: Peggy Deamer. "Structuring Surfaces: The Legacy of the Whites." 94
- 23 Hays, K. Michael. "Critical Architecture: Between Culture and Form" *Perspecta*, Vol. 21, (1984): 14-29
- 24 This built upon Diana Agrest and Mario Gandelsonas's previous work on "the structure of the exchange between architecture and ideology, of architecture as ideology": "Design versus Non-Design," paper presented 1974; published in *Oppositions* 6 (Fall 1976) found in *Architecture Theory since 1968*. (Cambridge, Mass: MIT, 1998), 198.
- 25 This ambition is described by Jeffrey Kipnis in "Is Resistance Futile?," *Log*, no.5 (Spring/Summer 2005): 105-109.
- 26 Althusser uses a systems model to describe the way parts of the superstructure maintain their relative autonomy from the base in a structured but decentered totality. See: Althusser, L. and Balibar, E. *Reading Capital*, trans. Ben Brewster (London: New Left books, 1970) 58.
- 27 C. A. Doxiadis, *Ekistics: An Introduction to the Science of Human Settlements* (New York: Oxford University Press).
- 28 "Delos Declaration," and "The Delos Symposium," in *Ekistics* 16 (October 1963).
- 29 Constant was a member of the COBRA, and Guy Debord originally suggested the name of the city "New Babylon." After 1960, Constant and Debord would no longer work together. Constant would continue to use some idea of "cybernetics" in this project and would work on it for another ten years. During the 1960s Guy Debord was against the use of Cybernetics. See: Guy Debord, "L* Avant-garde de la présence," *Internationale Situationniste* 8 (January 1963): 20. For an interesting history of Debord arguing with GRAV about the possibilities of cybernetics to critique the spectacle see: Lily Woodruff. "The Groupe de Recherche d'Art Visuel against the Technocrats" *Art Journal*, Vol. 73, No. 3 (Fall 2014), pp. 18-37. For a description of the New Babylon Project see: Mark Wigley, Constant's New Babylon: a Hyper-Architecture of Desire (Rotterdam, 1998). Hilde Heynen, 'New Babylon: the Antinomies of Utopia', in *Assemblage*, 29, April 1996, 25-39.
- 30 Kenneth Frampton in describing this event doesn't attribute this change to systems thinking but conception of community (Gemeinschaft). Kenneth Frampton, *Modern Architecture: a Critical History* (London: Thames and Hudson, 1985), 269-279. See also: Le Corbusier, *La Charte d'Athènes* (1942), trans. The Athens Charter (New York, 1973).
- 31 Contradictions in connecting these two models have been pointed out by Kenneth Frampton, and Allan Colquhoun, for the simultaneous interest in recovering "the lost 'wholeness' of craft-based communities and cultures" and at the same time looking to the future with "a capitalist world of open structures within which democracy, individualism, commodification, and an ethos of consumption." Quote from Colquhoun, *Modern Architecture*, 234.
- 32 Hans Ulrich Obrist, *Yona Friedman: The Conversation Series* (Köln: Verlag der Buchhandlung Walther König, 2007) Stanley Mathews, *From Agit Prop to Free Space: The Architecture of Cedric Price* (London: Black Dog Publishing, 2007) Yona Friedman, *Yona Friedman / Pro Domo* (NY: Actar, 2006) Peter Lang and William Menking, *Superstudio: Life without Objects* (Milan: Skira, 2003); Simon Sadler, *Archigram: Architecture without Architecture* (Cambridge: The MIT Press, 2005), pp.2-10; 192-8 Mark Wigley, *Constant's New Babylon* (Rotterdam: 010 Uitgeverij, 1999);
- 33 The first is for clearly defined objectives and is understood as the typical architectural process from schematic design to construction documents to construction administration. In the second, he cites Ashby's introduction to Cybernetics and looks at the ways linear feedback (a series of designs are created and tested against performance criteria then measure until one satisfies that

criteria). The third and final option, involves learned behavior and is important for "user-participatory systems", where the architect creates a process that receives its own comprehensive evaluation, revises and generates other solutions and sorts and records those solutions. James Boyce, "What is Systems Approach?" in *Rethinking Technology: A Reader In Architectural Theory*, Eds. William Braham and Johnathan Hale, (New York: Routledge, 2007). 181-189.

34 Often *Agrupacion Espacio* has been written about as a CIAM "franchise" located in Peru who devotedly read Walter Gropius and Siegfried Giedion. Instead, as Sharif S. Kahatt has shown, *Agrupacion Espacio*, was reading Mario Quesada's book on modern architecture, *Espace en el Tiempo*, and the group was publicly outspoken against large state infrastructure projects based on Roosevelt's Tennessee Valley Authority instituted by Manuel Prado. See: Sharif Kahatt, "Agrupacion Espacio and CIAM Peru Group" in *Third World Modernism: Architecture, Development, and Identity*, Ed., Duanfang Lu, (Routledge: New York, 2011). For a summary of La Carta de Machu Pichu See: Silvia Sterental, "The Charter of Machu Pichu, Testimony to the advocacy and pursuit of Enlightened Principles of Planning and Design in Profession, Education and Practice," in *The Fifth Column* (winter, 1982); 16-17. According to Kahatt, this document was signed by Oscar Niemeyer, Bruno Zevi, Kenzo Tange, Santiago Agurto, Luis Miro Quesada, Fernando Belaunde, Jose Luis Sert, Buckminster Fuller, Paul Rudolf, and Gordon Bunshaft. Sarraf Kahatt also says that "La Carta De Machu Picchu" was presented at the Congress of the UIA in December 1977 in Cuzco. I haven't been able to find any record of this event; it is my belief that the charter was written in Cuzco and intended for the 13th world congress of the UIA in December 1978 in Mexico City, where all the signers of the document were present.

REFERENCES

- Alexander, C. 1966. "A City Is Not a Tree," *Design*, No. 206 (February): 46-55.
- Ashby, W. 1956. *Introduction to Cybernetics*. New York: Wiley.
- Banham, R. 1999. *A Critic Writes: Selected Essays by Reyner Banham*. Berkeley, Los Angeles and London: University of California Press.
- Bertalanffy, L. 1969. *General System Theory: Foundations, Development, Applications*. New York: George Braziller.
- Boyce, J. 2007. "What is Systems Approach?" In *Rethinking Technology: A Reader in Architectural Theory*, edited by William Braham and Johnathan Hale. 408-421. New York: Routledge.
- Carpo, M. ed. 2012. *AD Reader: The Digital Turn in Architecture 1992-2010*. Chichester: Wiley.
- Colquhoun, A. 2002. *Modern Architecture*. Oxford: Oxford University Press.
- Deamer, P. 2001. "Structuring Surfaces: The Legacy of the Whites." *Perspecta* 32 (Resurfacing Modernism): 90-99.
- Doxiadis, C. 1968. *Ekistics: An Introduction to the Science of Human Settlements*. New York: Oxford University Press.
- Duda, J. 2013. "Cybernetics, Anarchism and Self-Organization." *Anarchist Studies* 21, no. 1 (Spring-Summer): 52-72.
- Forty, A. 2000. *Words and Buildings: A Vocabulary of Modern Architecture*. London: Thames and Hudson.
- Frampton, K. 1985. *Modern Architecture: A Critical History*. London: Thames and Hudson.
- Handler, B. 1970. *A Systems Approach to Architecture*. New York: American Elsevier Publishing.
- Haraway, D. 1985. "Manifesto for Cyborgs: Science, Technology, and Socialist Feminism in the 1980s," *Socialist Review* 80: 65-108.
- Harrison, A. 2013. *Architectural Theories of the Environment*. New York: Taylor & Francis Group.
- Hays, M. 1984. "Critical Architecture: Between Culture and Form." *Perspecta* 21: 14-29.
- Hays, M. 1998. *Architecture Theory Since 1968*. Cambridge: The MIT Press.
- Jacobs, J. 1961. *The Death and Life of Great American Cities*. New York: Random House.
- Kahatt, S. 2011. "Agrupacion Espacio and CIAM Peru Group" In *Third World Modernism: Architecture, Development, and Identity*, edited by Duanfang Lu, 85-110. Routledge: New York.
- Kaufmann, E. 1943. "Claude-Nicolas Ledoux, Inaugurator of a New Architectural System." *Journal of American Society of Architectural Historians* 3, no. 3 (July): 12-20.
- Kipnis, J. 2005. "Is Resistance Futile?" *Log* no. 5 (Spring/Summer): 105-109.
- Laurence, P. 2006. "Contradictions and Complexities: Jane Jacob's and Robert Venturi's Complexity Theories." *Journal of Architectural Education* 59, no. 3 (February): 49-60.
- Luhmann, N. 2012. *Introduction to Systems Theory*, translated by Peter Gilgen. Cambridge: Polity.
- Lynn, G. ed. 2004. *Folding in Architecture*. New York: John Wiley & Sons.
- Martin, R. 2005. *Organizational Complex*. Cambridge: MIT Press.
- Mathews, S. 2007. *From Agit Prop to Free Space: The Architecture of Cedric Price*. London: Black Dog Publishing.
- Maturana, H and F. Varela. 1992. *The Tree of Knowledge: The Biological Roots of Human Understanding*. Boston: Shambhala.

Systems Everywhere

- Mitchell, W. 2004. *Me++: The Cyborg Self and the Networked City*. Cambridge: The MIT Press.
- Moss, E. 2011. "Parametricism and Pied Piperism: Responding to Patrick Schumacher." *Log* no. 21 (Winter): 81-87.
- Obirst, H. 2007. *Yona Friedman: The Conversation Series*. Cologne: Verlag der Buchhandlung Walther König.
- Parsons, T. 1951. *The Social System*. Glencoe: Free Press.
- Perez-Gomez, A. 1983. *Architecture and the Crisis of Modern Science*. Cambridge: MIT Press.
- Perez-Gomez, A. 1993. "Introduction." In *Ordonnance for the Five Kinds of Columns after the Method of the Ancients, 1-44*. Santa Monica: Getty Center.
- Picon, A. 2011. "When Parametricism Tries to Reconnect with Vitruvius." *Log* no. 23 (Fall): 53-7.
- Rawes, P. ed. 2013. *Relational Architectural Ecologies: Architecture, Nature and subjectivity*. New York: Routledge.
- Sadler, S. 2005. *Archigram: Architecture without Architecture*. Cambridge: The MIT Press.
- Schumacher, P. 2011. "Parametricism and the Autopoiesis of Architecture." *Log* 21 (Winter): 63-79.
- Shanken, A. 2012. "The Tree in the System: Shifting urban paradigms in Mid-Century London," *Perspecta* 45, (Agency): 143-152.
- Turner, J. 1978. "Housing in Three Dimensions: Terms of Reference for the Housing Question Revisited." *World Development* 6, no. 9-10: 1134-1145.
- United Nations, Department of Economic and Social Affairs. 1973. *Integration of Housing into National Development Plans: A Systems Approach*. New York: United Nations.
- Varela, F., Maturana, H. and Uribe, R. 1974. "Autopoiesis: The Organization of Living Systems, its Characterization and a Model." *Biosystems* 5: 187-196.
- Venturi, R. 1966. *Complexity and Contradiction in Architecture*. New York: MOMA Press.
- Venturi, R., D. Brown, and S. Izenour. 1977. *Learning from Las Vegas*. Cambridge: The MIT Press.
- Wallerstein, I. 1974. *The Modern World-System: Capitalist Agriculture and the Origins of the European World Economy in the Sixteenth Century*. London: Academic Press.
- Ward, C. 1966. "Anarchism as a Theory of Organisation." *Anarchy* 62: 97-109.
- Wigley, M. 1999. *Constant's New Babylon*. Rotterdam: 010 Uitgeverij.
- Wigley, M. 2001. "Network Fever" *Grey Room*, no. 4 (Summer): 82-122.
- Wolfe, C. 1995. "In Search of Post-Humanist Theory: The Second-Order Cybernetics of Maturana and Varela." *Cultural Critique* 30: 33-70.
- Wolfe, C. 2010. *What Is Posthumanism?* Minneapolis: University of Minnesota Press.
- Woodruff, L. 2014. "The Groupe de Recherche d'Art Visuel against the Technocrats." *Art Journal* 73, no. 3 (Fall): 18-37.

AGENT BASED SEMIOLOGY: Simulating Contemporary Office Occupation Patterns with Simplified Social Models

Robert R. Neumayr
University of Applied Arts Vienna

Abstract: Knowledge economy has become an increasingly important factor in recent years. Office environments have changed accordingly, and contemporary office space layouts have become more complex, as their qualities rely on their capacity to enhance the continuous transfer of knowledge and information rather than the exchange of work or goods. As the performance of these types of spaces becomes more difficult to assess, new methods need to be developed.

The research methodology described in this paper aims to predict the complex emerging spatial occupation patterns in contemporary office environments. Its ambition is to develop a novel method of architectural design that generates spatial environments with high social performativity. Embedded in the conceptual framework of agent-based simulation, this research does not foreground the configuration of space itself (like other tools such as space syntax) but rather focuses on devising behavioral rules of social interaction for a set of active agents within the space in question, with the goal to develop a population of agents that is sophisticated enough to allow for the emergence of an abstract, yet plausibly life-like collective event scenario, within an office space that features typical elements of interaction such as tables, desks and coffee bars. Behavioral patterns are driven by a carefully constructed simplified social model that differentiates agents according to their “social attractiveness” and their “social alignment”, which govern the rules of interaction with other agents and objects in space. Results show that all simulations exhibit an overall life-like behavior when run and observed. Agents show differentiated behavior towards other agents and frame dependency to the varying distribution of objects in their space. Different space layouts result in differentiated spatial occupation patterns. While the overall number of interactions remains stable across all scenarios, the numbers for interactions with objects differ considerably depending on their location in space, indicating that different object formations within the same space influence the individual number of interactions and therefore render a space more or less performative.

Keywords: Agent-based semiology, work and office environments, contemporary spatial occupation patterns, digital design, social performance simulation, human space design

INTRODUCTION

The built environment orders all social processes through semiological connotations as much as through physical boundaries. In this way, it guides and orients socialized agents, who need to understand and navigate their environment, via the comprehensibility of its visual representation to the same extent to which it channels physical bodies through its space. The “performance” of space, therefore, depends on its configuration, as well as on its capacity to appropriately frame its users’ communications in context-sensitive ways.

Measuring and improving the performativity of office space and the workflow within it has been a topic of constant research since the second half of the 19th century, when Frederick W. Taylor began to develop his theory of scientific management. Since then, the nature of work and its underlying concepts have evolved considerably. Spatial layouts have become more diversified and interwoven and, as a consequence, the tools and methods of space analysis and evaluation have changed and matured too.

Soon after the traditional Taylorist office space layouts with their linear logic of mono-directional workflow had proven to be inadequate for the increasingly complex patterns of work that had emerged over time, designers started to develop innovative design strategies, such as the German Quickborner team’s Bürolandschaft concept, whose office configurations were directly derived from the matrices and diagrams used to analyze the relations between different groups of co-workers within an office organization.

Although the concept still followed a strictly linear understanding of spatial distribution and workers’ interaction, it offered two key innovations for the further development of office space design: for one, rather than content, it focused on patterns of communication, in order to use the flow of information as a generative tool. At the same time, it put an end to long-held spatial hierarchies, thus promoting informal face-to-face interaction, which was considered crucial in a cybernetic organizational model (Kockelkorn 2008).

In work environments that depend on a mostly linear transfer of work and goods, rather on the multi-directional exchange of information and knowledge, the success of a specific spatial configuration could be easily measured, for example by looking at the amount of paperwork done, or units assembled. Yet the performance of contemporary office space layouts that are designed to accommodate more complex social interaction patterns are much more difficult to assess.

1. TOOLS FOR ANALYSIS AND SIMULATION

1.1. SPACE SYNTAX AS AN ANALYTICAL TOOL

Of all the tools and techniques that have been established over the years to understand social spaces, space syntax remains the most popular and successful. Developed by Bill Hillier and Julienne Hanson, who—for the first time—proposed to look at the built environment, rather than as a mere aggregation of volumes and voids, as a social system that needs to be analyzed “... at the level of [a] system of spatial relations that constitute the building or settlement” (Hillier and Hanson 2003, 3) in order to understand societal effects in play. Initially developed to study and evaluate the varying patterns of public streets and squares in small hamlets, space syntax research was soon extended to investigate building interiors and other indoor social spaces. Space syntax today is widely used as a tool to understand the relationship between the morphological characteristics of office spaces, their occupational patterns, and the locations and frequency of the personal interactions of its users. Most commonly, this is achieved by applying space syntax's analytical concepts, such as integration, space, depth distance, and isovists, in order to quantify the configurational properties of a space. The results are then correlated to information about social interaction collected in the space or compiled from surveys or questionnaires taken by the employees working in that space or derived from network analysis (Peponis et al. 2007).

In his introduction to space syntax, Bafna summarizes that, “The primary object of analysis within space syntax research, then, is the configured space” which is “... redescribed in an abstracted format focusing on its topology”. The premise at the base of this analytical procedure is “... that the sociologically relevant aspects of configured space can be captured at the level of topological description” (Bafna 2003, 19).

Recent studies, however, seem to indicate that, within the spatial constraints of a typically sized office space, social factors, such as an employee's position within an organization's hierarchy, her level of expertise or her membership with a specific group or department, outweigh spatial parameters, as “... managerial staff and experts are also attractors in the spatial

system.”, as Steen and Markhede observe (2010, 123). Therefore, in some instances, space syntax analysis produces inconclusive results, as the exact quantitative description of the space in question can no longer be matched to the changing patterns of interactions observed in the space.

Emerging spatial occupation patterns in contemporary office spaces, therefore, seem to increasingly rely on the interactions of the occupants (“agents”) within their system and the social and semiological attributes that drive that behavior. As a consequence, the performance of a space can no longer be accurately measured by space syntax methodology alone, and the existing set of tools needs expansion to allow for the analysis of relational properties between a system's agents and their environment, in order to evaluate and refine spatial layouts.

1.2. AGENT-BASED SIMULATIONS

Within the last few years, knowledge economy has become an increasingly important factor in almost every developed country's service sector. In Western European countries, for example, knowledge economy at this point represents about a third of all economic activities (Eurostat 2013). As the economy's focus has shifted from the exchange of work or goods to constant human interaction and the transfer of information, various innovative types of knowledge work, with their respective mobility patterns, have emerged (Greene and Myerson 2011). Contemporary office space layouts accordingly become more multi-functional and interwoven, as their quality hinges on their capacity to facilitate formal and informal exchange of information between actors in complex and ever-changing configurations.

It is therefore the working hypothesis of this research, that in today's dynamic environments, spatial occupation patterns are no longer static or linear in nature, but start to show unpredictable and emergent configurations, which can be understood as the result of a multitude of (comparatively simple) interactions of the users of the environment in question, which gradually add up to the complex state of an emerging system. The results of such a bottom-up process can no longer be predicted by looking at spatial configurations but need to be understood by investigating the relationships between the actors within the space.

They can, therefore, be simulated using agent-based modeling (ABM), which in its most concise definition is “a computational method that enables a researcher [to] experiment with models composed of agents that interact within an environment” (Gilbert 2008, 2).

Craig Reynolds' computer simulation “Boids” (Reynolds 1987), in which he successfully reproduced the flocking behavior of birds in 1987, is generally

considered the first agent-based simulation. Since then, the field of application for agent-based models has diversified and they are widely used for simulations in diverse fields, from biology to social sciences, mapping the processes that we assume to exist in a real social environment (Macy and Willner 2002).

However, architecture has only recently discovered them for the simulation of crowds in space. Similar to a flock of birds, human crowds show non-linear behavior, caused by the recurring iteration and superimposition of the interactions of their constituent components, which add up to the complex overall state of the system. They constitute emergent systems that can be studied and understood using agent-based modeling.

While plenty of commercial software programs offer readily available tools for crowd simulation, more complex life process simulations still require some scripting knowledge and the use of more specialized programs. For this research I will use NetLogo as an agent-based modeling and scripting language. NetLogo is a program designed for agent-based simulations, with built-in processes that are already designed to solve typical agent-based simulation scripting problems. It is open source software and caters to an academic environment. It is therefore easily accessible and draws from a large and active user community as "... there are a large number of agent-based models written in NetLogo in a wide variety of domains" (Wilensky and Rand 2015, xiv). As it is purely code based, it is fast, scalable and data extraction is easy. However, NetLogo's representational capacities are basic and visual output is limited to simple 2.5D graphic representation.

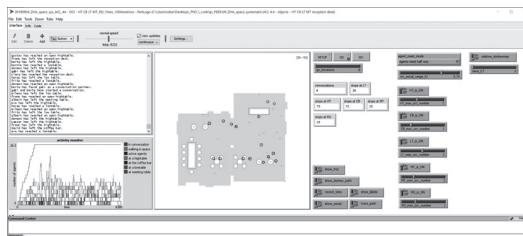


Figure 1: The NetLogo interface for the simulation. From left to right column: data readout windows, graphic representation of the simulation space, control panel. (Author, 2018)

2. RESEARCH METHODOLOGY

2.1. SIMULATION SETUP

In general, all agent-based simulation share the same set of characteristic features: ontological correspondence, a representation of the environment in question, a set of heterogeneous agents, and agent interactions based on bounded rationality (Fagiolo, Windrum, and Moneta 2006).

In this simulation, as an experimental setup, I use the layout of a contemporary office environment, which is modeled after an existing office in London. The research focuses on the office space's breakout space, which can be considered its most informal area, where face-to-face interaction can easily occur. Within the space, various typical office furniture elements are located; that foster unscheduled and spontaneous communicative encounters, but also allow for organized variously sized meetings and conferences in different constellations.

The space will be populated by sixteen agents, who enter and leave the space through one of the three available thresholds and navigate the space in order to interact with each other and the furniture elements at their disposal.

2.2. DEVELOPING A SIMPLIFIED SOCIAL MODEL

In office space research, the correlation between spatial proximity and the rate of face-to-face communication is well researched. Personal interactions, for example, decrease exponentially as the distance between a space's population increases, a relation whose graph is known as the Allen Curve (Allen 1984). However, more recent space syntax based research suggests that this discovery is accurate only for largely static office settings, whereas in more dynamic office environments, where a lot of circulation occurs, there is a strong correlation between interaction frequency and the intervisibility of the workers in the space (Markhede and Koch 2007).

Taking this into account, the research focuses on developing and refining agent-based simulations, in which the agents' behavioral rules and scripts are prompted not so much by distance or the position of the agent in relation to the space around him, but mainly by the social interaction with other agents and specific spatial or environmental features. The aim is to develop a population of agents with individual behavioral rules that are sophisticated enough to allow for the emergence of a simplified, yet plausibly life-like collective event scenario. For this, any agent-based simulation needs to include two key features of process modelling, agent differentiation and architectural frame dependency, allowing it to "move from the current evacuation and traffic-engineering crowds to architectural and semiological crowd, as the basis for generalized life-process simulation" (Schumacher 2016, 112).

Agents need to be differentiated by their position, status, group membership or importance within the social network, resulting in behavioral differences as they interact with each other. Agents also need to show architectural frame dependency, allowing for varying behavioral patterns depending on their location within a space and its architectural qualities.

This research aims to map complex real-life social interactions to a simplified social model for its agents, weighing the multiple variables in play in order to make them operational in a simulation.

2.3. SIMPLIFICATION AND BOUNDED RATIONALITY

Almost all social science research is conducted by devising simplified representations of social phenomena. In agent-based modeling, agents need to be understood as computational processes, which are coded in order to model human capabilities in a highly simplified way. Computational agents are, therefore, always limited in their cognitive abilities; they are modeled to act with bounded rationality.

The concept of bounded rationality was first introduced by Herbert A. Simon (1957), who suggested that, rather than assuming that an individual's choices are perfectly rational, one should understand the rationality within any decision-making process to be limited, as the amount of information is limited; human minds only have a limited capacity of evaluation and there is only a limited amount of time to make a decision.

It is safe to assume that the complex and changing occupational patterns in contemporary office spaces are influenced by a multitude of different non-spatial factors, albeit to a different degree. These factors might be differentiated into quantitative factors, such as fellow agents, office objects or architectural features, and qualitative factors, such as light, temperature, cultural context, or work atmosphere. While quantitative factors will trigger certain interaction patterns, qualitative factors might influence the probability, intensity, duration or sequence of these patterns.

In this research, the agents' behavioral abilities are developed gradually, starting from quite simple rules of interaction. The challenge is therefore "... not to limit the rationality of agents, but to extend their intelligence to the point where they could make decisions of the same sophistication as is commonplace among people" (Gilbert 2008, 16). The simulation needs to be set up in a way that allows for the implementation of the agents' capacities in different stages, first focusing on the ones that are considered most important.

2.4. BASIC PARAMETERS OF SOCIAL INTERACTION

The research, therefore, investigates the basics of spontaneous face-to-face conversation first, and focuses on two essential questions: "Who interacts with whom?" and "How long does this interaction last?". The dynamics of the interactions taking place between agents within the simulation space is described by operationalizing two values that are conceived to be numerical representations of the complex social parameters that drive these relations.

The selection process for possible conversation partners is governed by a variable called "social attractiveness" that quantifies the social differentiation between the agents (such as social status, hierarchy, knowledge or information or physical attractiveness) and is defined by a value from zero to one. In general, agents will always try to interact with the agent with the highest social attractiveness present at any time in the simulation. However, some constraints apply. Agents will always operate within two different ranges, confining their respective interaction radii. First there is a "physical range" limiting the set of available agents to those within a pre-set spatial proximity defined by distance and visibility. Then, more importantly, we introduce another parameter called "social range", which sets the maximum difference in social attractiveness that still allows for social interaction.

While the physical range, in a simplified way, defines the spatial limits of successful personal communication, the social range, which is developed for this set of simulations, starts to describe the relationship between patterns of communication and the social environment they are embedded in. It defines the permeability of the hierarchical structures of a specific corporate (or societal) culture, also drawing on the observation that the constellations, frequency and duration of conversations will be considerably different in culture groups with divergent concepts of hierarchy. It reflects observable restrictions from real-life social scenarios, where big differences in status or hierarchy usually preclude social interaction. The social range consequently defines a sub-set of agents with whom a specific agent is socially allowed to engage. Furthermore, agents who are already engaged in some sort of interactivity are considered unavailable for interaction.

In this simulation, agents will therefore always look for and try to interact with an available agent with the highest social attractiveness within its social and physical range.

The duration of any social interaction is determined by calculating differences of value of a variable called "social alignment". It represents an agent's personal properties (such as personality, profession, expertise, fields of interest and knowledge, or acquaintances) as a vector with a directional value between 0 and 360 degrees. The more the vectors of two interacting agents align (i.e., the more they have in common), the longer their interaction will last.

It should be added, that at this point of the research, all values that determine the agents' behavioral properties are assigned randomly as placeholders that can later be substituted by more viable social data, which can, for example, be extracted from social network analysis.

Systematic modulations of the values for the agents' social and physical range will generate a number of distinct spatial occupation patterns. For example, setting a high value for physical range and a low value for social range will result in longer travel distances and fewer social interactions. Inverting these values on the other hand will lead to a high number of social interactions within a small spatial field.

It is reasonable to assume that in clearly confined office spaces not only fellow agents, but also inanimate objects will influence the spatial occupation patterns of its users. Steen and Markhede (2010) also notice this, stressing the equal importance of "hard artefacts" and "office workers" in the analysis of spatial and social configurations in offices (123). This is especially true for common areas, such as lobbies, break rooms, or communication spaces, where one would expect to find office elements such as coffee bars, reception desks, high tables, low tables, and meeting tables in various configurations; that cater for common, yet always temporary, needs and desires of their users, triggering frame dependent behavior.

For the scope of this set of simulations, the simplified social model developed for the agents is equally applied to the office objects in it. Values are assigned as placeholders for characteristics that might influence the attractiveness of a specific element, like the type of an object (such as coffee bar or high table) or its location within the office space (for example next to the entrance, in the middle of the room, or in a remote corner). Coffee bars almost always have a rather high level of social attractiveness. Similar to the rules applied to person-to-person interaction, a combination of agents and objects will temporarily acquire new combined values for social attractiveness and social alignment for as long as they interact with each other. For example, a remote table's attractiveness will increase with managerial staff standing next to it, whereas agents with low social attractiveness populating the coffee bar will decrease this combination's overall value, thus making it approachable for a different subset of agents, as any agent will always attempt to interact with the set of entities that has the highest attractiveness within its social and physical range.

Again, every modification of the physical and social ranges of agents and objects will create distinctively different patterns of spatial occupation and interaction. Setting high ranges for agents and low ranges for objects will, for example, lead to a high rate of free-floating agent-to-agent conversations and little interaction with the objects in the space. Setting high ranges for objects and low ranges for agents on the other hand will result in frequent agent-object interaction and almost eliminate personal conversations from the simulation.

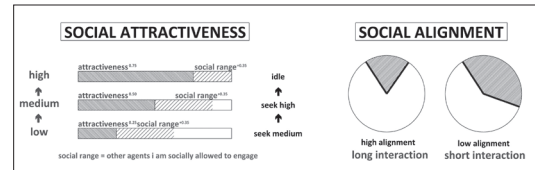


Figure 2: Social Attractiveness and Social Alignment are defined as the key variables that drive the agents' behavioral patterns in a simplified social model of interaction. (Agent-based Parametric Semiology Research Group–Josip Bajcer, 2017)

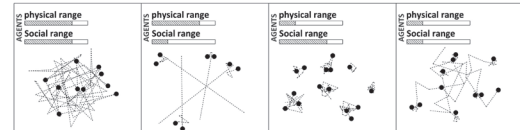


Figure 3: Different values for an agent's social and physical range will generate a wide variety of different spatial occupation patterns. (Agent-based Parametric Semiology Research Group–Josip Bajcer, 2017)

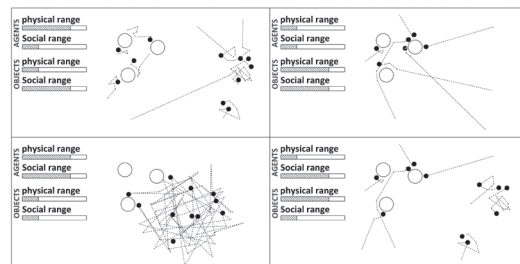


Figure 4: Different values for social and physical ranges of agents and objects will generate a wide variety of different spatial occupation patterns. (Agent-based Parametric Semiology Research Group–Josip Bajcer, 2017)

2.5. SETTING UP A RESEARCH MATRIX

While the random walk, a sequence of randomly directed individual steps that are strictly independent of one another on a two-dimensional plane is often described as the most simple concept of movement in an agent-based model (O'Sullivan and Perry 2013), the starting point for this simulation is a rudimentary agent model with agents wandering around unaware of themselves and each other, walking without interaction or collision avoidance towards randomly assigned targets within a given range. Subsequently, the simulation's complexity is increased step by step to develop a generic agent model with fundamental navigational properties.

The simple social model described above is then implemented on top of this successfully tested generic agent model, which at this point already contains scripted processes for spatial navigation, simple fields of vision, collision avoidance, object and agent recognition, and detection of entrance and exit areas.

In subsequent steps, the agents' capabilities are systematically extended to allow for patterns of interaction with a number of common office furniture elements taken from the office layout developed earlier, such as high tables, low tables, a meeting table, a reception desk, and a coffee bar.

As in other strands of digital design research, repeatedly testing and refining the scripted processes becomes important for a systematic approach to problem solving, once a basic logic has been established (Neumayr and Budig 2009). For improved systematic comparison, simulations are therefore organized in a 2-dimensional matrix. The vertical axis holds the levels of agent complexity (agent capacity level–ACL), starting with the simplest possible agent as described above (ACL 1.0) and ending with—at this point— behavioral rules for the interaction with five different furniture elements (ACL 4.4).

The result is a cumulative buildup of potential agent capacities that allows for direct comparison of the different levels of complexity and, as a consequence, offers insight into the relevance of specific agent capacities in relation to the agents' simulation environment.

On the horizontal axis, four parallel office scenarios are simulated for each agent capacity level, in order to produce a reliable set of data. While the number and type of office furniture and interaction objects, as well as the number of entry and exit points, stay the same for each of the scenarios, their locations in the space varied systematically. In each simulation, the maximum number of agents (sixteen) and the simulation time of thirty minutes remain unchanged. During simulation runtime, all relevant information, such as every agent's position (in one second intervals), their speed, direction, and path, but also the time, location, and duration of their interactions and encounters are recorded and stored in a data base for later analysis and comparison. For each scenario, the simulation is run 100 times in order to check for consistence, minimum and maximum values, average, standard deviation, and outliers. The data collected is first used to create a number of graphs and visual quantifiers, such as heat maps (showing the occupation patterns over time), location maps, and trail maps tracking the movement of each individual agent.

3. SIMULATION RESULTS AND FINDINGS

All agent-based office space simulations, that are based on the simplified social model are assessed on different levels.

To begin, in order to check for plausibility, all agent behavior is evaluated according to their susceptibility to agent differentiation and frame dependency. In a first step this is done by analyzing a simulation's visual output during runtime. During simulations, agents show differentiated behavioral patterns towards other agents



Figure 5: Heatmaps of the simulation of three different office space layouts (GG, HH, II), showing the different patterns of agent occupation resulting from the varying location of objects. (Author 2019)

holding varying social properties, as well as towards objects of interest distributed in the space. Observations show that the selection process for social interaction and spatial occupation follows an intricate set of instructions and does not result from simple rules, such as distance or visibility.

This observation is confirmed by comparing the heat maps of different simulation setups. Heat maps show the occupation patterns of all agents accumulated over time and superimposed in one image. As the objects' positions in the space vary across different simulation setups, the agents' behavior (and with it their locations in the space) shifts and adapt accordingly.

In terms of consistency and frame dependency simulation, results are assessed by analyzing the agent data recorded during each simulation. Here, the frequencies of the various agent-to-agent and agent-to-object interactions were investigated.

Looking at a series of simulations in an identical and closely confined simulation space, with a fixed number of active agents and a constant number of interaction objects, whose positions are strategically modified to be different in each simulation, one would expect to find a similar, yet not identical, total number of interactions, but at the same time diverging values for the agents' interactions with the objects in the space.

The numbers taken from the three simulations in ACL 4.4 confirm this expectation: While the total number of interactions for all sixteen agents lies between 204 and 208 and therefore does not change significantly, the values for agent-to-agent conversation (free conversations) and various agent-to-object interactions vary considerably from simulation to simulation. The number of free conversations ranges from 13 to 43, values for high table interaction ranges from 61 to 95, for low tables from 31 to 41, for the reception desk from 11 to 16, and for the meeting table from 27 to 47. The interaction value for the coffee bar, which is always located next to a wall, shows the smallest variance (from 15 to 17).

The information from the first three simulation scenarios in every ACL are also used to train a statistics-based prediction algorithm to forecast the spatial occupation pattern for the fourth scenario. The

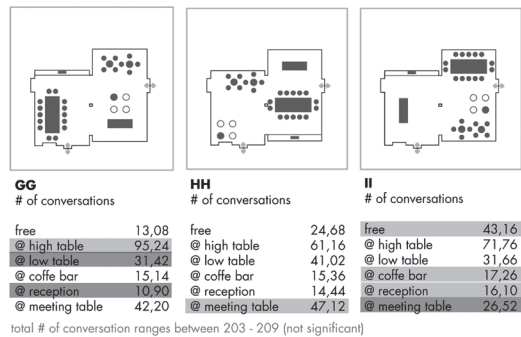


Figure 6: Table of interaction frequencies for three different scenarios (GG, HH, II). Green and Red indicate maximum and minimum values for the interaction with specific objects within the entire set of simulations. (Author 2019)

algorithm's results are then compared to the results of the agent-based simulation of that scenario condition for consistency. Details about this related strand of research were recently published in a separate research paper (Fuchs and Neumayr 2020).

DISCUSSION AND OUTLOOK

As of now, the simulations developed for this strand of research show an overall life-like behavior when run and observed. Agents exhibit differentiated behavior towards other agents and frame dependency to the changing object distribution in the simulation space. The cumulative behavior over time results in differentiated spatial occupation patterns throughout different scenarios.

The overall number of interactions remains stable across all scenarios, whereas the numbers for individual

interactions vary significantly from one simulation to another, indicating that different object formations within one and the same space do indeed influence the number of interactions, and—as a consequence—render a space more or less performative.

Based on these findings, further explorations are necessary, with the aim to discover more reliable correlations between the objects' locations and the resulting interaction numbers.

At this time, the question of the realism of these simulations is difficult to answer. In this respect, more experimental investigation will be necessary, as well as calibration of the simulation results with observations, and sensor data collected in the office space that is simulated here.

I will also argue that, in order to comparatively evaluate and select the most suited design alternative from within a design space, no absolutely accurate performance measurements are necessary. The empirical notion that a spatial organization's relative advantages in performativity can be accurately described, even if absolute performance measures might be imprecise, appears as a valid first step, warranting further investigations into this design methodology.

ACKNOWLEDGEMENTS

This research is part of a joint research venture, generously funded by the Austrian Science Fund (FWF) PEEK–project AR 354-G24. My appreciations go to Patrik Schumacher and to my fellow researchers Josip Bajcer, Daniel Bolojan, Mathias Fuchs, and Bogdan Zaha for their invaluable insights and comments.

REFERENCES

Allen, T. 1984. *Managing the Flow of Technology: Technology Transfer and the Dissemination of Technological Information Within the R&D Organization*. Cambridge: MIT Press.

Bafna, S. 2003. "Space Syntax A Brief Introduction to Its Logic and Analytical Techniques" *Environment and Behaviour* 35, no. 1 (January): 17-29.

Eurostat. 2013. *Science, Technology, and Innovation in Europe*. Luxembourg: Publication Office of the European Union.

Fagiolo, G., P. Windrum, and A. Moneta. 2006. "Empirical Validation of Agent-Based Models: A Critical Survey." *LEM Working Paper Series* 14: 1-44.

Fuchs, M. and R. Neumayr. 2020. "Agent-Based Semiology for Simulation and Prediction of Contemporary Spatial Occupation Patterns" In *Impact: Design with All Senses*, edited by C. Gengnagel, O. Baverl, J. Burry, M. Ramsgaard Thomsen, and S. Weinzierl, 648-61. Cham: Springer.

Gilbert, N. 2008. *Agent-Based Models*. Thousand Oaks: Sage Publications.

Greene, C. and J. Myerson. 2011. "Space for Thought: Designing for Knowledge Workers." *Facilities* 29, no. 1-2 (February): 19-30.

Hillier, B. and J. Hanson. 2003. *The Social Logic of Space*. Cambridge: Cambridge University Press.

Kockelkorn, A. 2008. "Bürolandschaft – eine vergessene Reformstrategie der deutschen Nachkriegsmoderne." *ARCH+ Zeitschrift für Architektur und Städtebau* 186-187: 6-7.

Macy, M. and R. Willner. 2002. "From Factors to Actors: Computational Sociology and Agent-Based Modeling." *Annual Review of Sociology* 28: 143-166.

- Markhede, H. and D. Koch. 2007. "Positioning Analysis: Social Structure in Configurative Modelling." In *Proceedings, 6th International Space Syntax Symposium, Istanbul, vol. II*, edited by A.S. Kubat, Ö. Ertekin, Y. I. Güney, and E. Eyüboğlu, 69.1-69.14. Istanbul: ITU Faculty of Architecture.
- Neumayr, R. and M. Budig. 2009. "Generative Processes – Script Based Design Research in Contemporary Teaching Practice." In *Innovative Design and Construction Technologies*, edited by I. Paoletti, 172. Milan: Maggioli.
- O'Sullivan, D. and G. Perry. 2013. *Spatial Simulation. Exploring Pattern and Process*. London: Wiley.
- Peponis, J., S. Bafna, R. Bajaj, and J. Bromberg. 2007. "Designing Space to Support Knowledge Work." *Environment and Behaviour* 39, no. 6 (July): 815-40.
- Reynolds, C. 1987. "Flocks, Herds, and Schools: A Distributed Behavioral Model." *ACM SIGGRAPH Computer Graphics* 21, no. 4 (August): 25–34.
- Schumacher, P. 2016. "Advanced Social Functionality Via Agent-Based Parametric Semiology." *Architectural Design* 86, no. 2 (March/April): 108-13.
- Simon, H. A. 1957. "A Behavioral Model of Rational Choice." In *Models of Man; Social and Rational*. New York: Wiley.
- Steen, J. and H. Markhede. 2010. "Spatial and Social Configurations in Offices." *The Journal of Space Syntax* 1, no. 1: 121–132.
- Wilensky, U. and W. Rand. 2015. *An Introduction to Agent-based Modeling: Modeling Natural, Social, and Engineered Complex Systems with NetLogo*. Cambridge: MIT Press.

DESIGNING 'SAFE' SCHOOLS: Identifying Areas of Research in Achieving School Safety and Security

Michael S. Nowak
Pennsylvania State University

Abstract: Multiple stakeholders have an interest in making our schools 'safe' places to learn and work. Among these are students and parents, law enforcement officials, school administrators and teachers, code officials, and architects. Each party approaches the concept of 'safe' from varying institutional logics defined by their professional culture or place in society. Institutional logics represent frameworks for how people in society can frame an issue and help guide them to solve problems. These logics can be complementary or competing. One issue is finding common ground defining the problem and finding a common language with which stakeholders can communicate and work together. Another is understanding how practices and customs differ between stakeholders. Knowing how each party frames the issue of 'safe' or 'secure' schools' aids in finding solutions to impasses where logics conflict through more holistic definitions. It also allows us to empirically know varying approaches to problem solving and where research is being conducted on the issue. The American Institute of Architects has lobbied the US government to establish a "Safe Schools Clearinghouse". Conceived as a repository of best practices for 'safe' school design, this clearinghouse encourages experimental research by design schools. Research would be the foundation for decision-making by local school districts and would encourage the development of new technologies in school safety. However, there currently appears to be a lack of safety or security research within our architecture schools. To understand where academia is on the issue of school safety research, this paper explores, through a contemporary literature review, the areas of peer-reviewed research on four key terms: "safe schools", "school safety", "school security", and "school shootings". The results indicate that the topic of school safety is absent in architecture academia, and most prevalent in the fields of psychology and education. While there is much literature on school safety outside academia sharing ideas, opinions, and case studies of design practices, no rigorous research appears to be being conducted in our design schools offering the validity necessary to make prudent decisions. If architects are expected to act as arbiters of best practices to guide and educate society on the design of 'safe' schools, then research within our design schools must begin now.

Keywords: Safe schools, institutional logics, security, safety

INTRODUCTION

Safety and security demand architectural attention. We all share an interest in occupying spaces that are free from harm, whether intentional or accidental. Building codes demand our buildings be able to withstand fire and destructive natural forces, provide for the introduction of fresh air and clean water, and that waste be safely removed. Human-caused harm in the built environment is left unaddressed by our codes with the assumption that design has no impact on behavior. Although research has shown a connection between design and crime (Jeffrey 1971; Newman 1973; Crowe 2000), architects often leave the question of security to others who may have conflicting vested interests that can prove to be detrimental to the safe enjoyment of space. Without proper attention, the spaces we create can harbor feelings of unease and may breed illicit activity.

This paper aims to identify the various academic fields conducting research on issues of school safety and security. Through a methodical literature review

process, various academic fields are investigated for research that has been conducted in the previous ten years. It is hoped that through this process we can learn where architecture stands among other academic fields, as well as how academic research writing compares to non-academic writing found in trade journals, newspapers, or professional magazines.

Understanding where architecture fits within the discussion allows us to identify other approaches and points of view on the issue. Because architectural projects involve a multitude of stakeholders, having a broader awareness of how other fields approach the issue allows for improved understanding and negotiation of disagreements in making decisions. Alternative approaches to the concepts of safety and security may hinder the ability to adequately implement effective solutions to safety and security problems. Physical or social science-backed research can help alleviate these differences and prepare the architect with solid evidence in support of an agreeable solution.

It also helps to advance the safety and welfare of clients and the public by providing a vital resource to those decision makers tasked with designing safe and secure learning spaces.

1. SAFETY OR SECURITY? IS THERE A DIFFERENCE?

1.1. DEFINING SAFETY AND SECURITY

What defines a school to be safe or secure? Is a safe school one in which no mass shootings occur but children are bullied or harassed on a regular basis? Is the absence of a mass shooting definitive of a 'safe' or 'secure' school? If this were the case, any school suffering from mass shootings would have been "safe" the day before such events occurred. The terms safety and security are often used interchangeably because they are multidimensional in meaning. This usually isn't problematic but finding a clearer definition could be useful. Bucher and Manning (2005) have stated that defining a school to be safe or unsafe can be problematic. In order to measure how "safe" or "secure" a school is, working definitions should be developed so that concepts of safety or security can be operationalized.

According to Bucher and Manning (2005), "A safe school is one in which the total school climate allows students, teachers, administrators, staff, and visitors to interact in a positive, nonthreatening manner that reflects the educational mission of the school while fostering positive relationships and personal growth" (56). This definition identifies a wider understanding of safety that includes both physical and psychological factors. Safety for the purpose of this research is understood as that state of being protected from hurt or injury resulting from unintentional, non-human caused events. This is how our building codes address the protection of human life from events that may be natural, industrial in nature, or that result from accident. These events include earthquake, hurricane, or fire.

Security can be defined as a state where an individual is unthreatened by a violation of rights, including freedom from physical harm (by another) (OED). Security may also be defined as a psychological feeling of safety (OED). This second understanding of security addresses concerns of all students' right to freedom from abuse, either physical or verbal. Security, for the purpose of this research, is defined as protection against hurt or harm from human-caused intentional acts. Such acts may include mass shootings, bullying, or sexual assault. It does not include natural threats.

Considering the violence aspect of safety (or security) Mayer and Furlong (2010) state that there has been a lack of consensus on what constitutes school

violence and disorder. Within the spectrum of school violence are multiple behaviors that have come in and out of inclusion. Astor, Guerra, and Van Acker (2010) have asserted that the scope of the term has expanded over the years and results in a "broader concept of school safety" (69). Astor, Guerra, and Van Acker (2010) have identified behaviors included under the umbrella of school safety, as being also labeled aggression, bullying, and violence. These behaviors may also include verbal assaults or exclusion from social groups. Within the literature, safety has come to include such factors or issues as gun violence, bullying, fire, trauma (observing violence against others), fear of crime, equity and inclusion, sexual violence, suicide, terrorism, weapons, hazardous materials, gang activity, harassment, cybersecurity, or bomb threats.

For the purpose of this research, a safe school is defined as a place where children can learn free from violence and in an environment conducive to mental and physical wellbeing. As such, mental and physical wellbeing includes freedom from bullying that is both physical and psychological in its forms, allowing children to focus their attention on academic and personal growth. Such environments are welcoming, promote school identity, and are healthy climates for participation and growth.

1.2. CONFLICT AND INTERCHANGEABILITY OF TERMS

Safety and security can be understood to be distinctly different depending upon which stakeholder is discussing the issue of school safety. A law enforcement officer may view a safe school to be one free of weapons and drugs. A school psychologist may see safe schools as being those where students are free from mental stressors that impede their ability to interact with teachers and fellow students and foster a sense of belonging. For a building code official, a safe school is one with adequate egress and adequate building systems. Interchangeability of the terms safety and security can shift the concept of safety along a scale of pure safety and pure security, depending upon each stakeholder's sense of place within society and the dominant institutional logic they possess.

2. INSTITUTIONAL LOGICS

2.1. WHAT ARE INSTITUTIONAL LOGICS?

Stakeholders are members of various institutions who frame their understanding of issues through the practices and customs by which they approach tasks that influence individual and organizational behavior (Thornton, Ocasio, Lounsbury 2012, 2). Each stakeholder interested in safe schools approaches the issue from

their unique institutional logic. Institutional logics, as defined by Friedland and Alford (1991), as cited by Berg Johansen and Waldorff (2017) are “A set of material practices and symbolic constructions [that] constitute organizing principles for supraorganizational patterns of human activity” (248). Berg Johansen and Waldorff (2017) describe institutional logics as “Sets of symbolic meaning and practices which coexists and create friction and actors’ perceptions of social reality (11).

Berg Johansen and Waldorff (2017) state that institutional logics guide and are guided by institutional orders designated as market, corporation, profession, state, community, family, and religion. Institutional logics represent a framework for the ways in which we approach problems based on our own customs, education, membership in different groups, and generally define our motivations and reasoning behind those. These motivations and reasonings can be vastly different depending upon the basic institutional orders we occupy. Often, these various logics can lead stakeholders to resist seeking other opinions believing they are uniquely suited to solve the problem. Rather than working in collaboration, institutional logics can create barriers to developing more holistic solutions. However, they can also provide alternative perspectives in developing solutions. This is where leadership in creating innovative solutions is useful.

Orders present among interested stakeholders of safe schools include profession (architects, engineers, teachers, and psychologists), state (school administrators, law enforcement, code officials, and the Fire Marshall), corporation (district), community (tax payers and concerned citizens), family (parents and siblings), and market (building material vendors and security consultants). Many stakeholders exist within multiple orders, such as architects as professionals, business owners, parents, and members of the community. Which order dominates can vary. Many of the parties within these orders may have conflicting approaches to solving the problem of ensuring a safe and healthy place to learn. Where friction occurs between orders, there is opportunity for innovation. However, sometimes these frictions are the result of impassable conflict. A lack of understanding of logic perspectives can delay a project or lead to animosity.

2.2. FRICTIONS BETWEEN LOGICS PRESENT IN SCHOOL SAFETY AND SECURITY

A market order that seeks to maximize profit by providing a good that satisfies a perceived need of the school district can conflict with a state order of enforcing the building code if such a product interferes with egress. For example, in the case of a security lockdown, a more robust locking mechanism might

enhance security, but may degrade safety through impeded egress. Security surveillance systems may offer greater physical security but may negatively impact the psychological wellbeing of students. Security features in the physical environment can be associated with undesirable effects on students (Schreck and Miller 2003). These features include metal detectors, cameras, locked doors, hall monitors, and security personnel. Lamoreaux (2017) found negative effects associated with metal detectors including increased fear of crime, that metal detectors are associated with increased student concern for their safety, that student fears are compounded with the addition of increased security measures (Perumean-Chaney and Sutton 2013), and that students at schools with metal detectors feel significantly less safe than students at schools without them (Gastic 2011; Hankin, Hertz, Simon 2011). A school psychologist might disagree that such effects provide an increase in safety given the psychological discomfort they bring. School psychologists lie within a profession order. In this scenario the market and profession orders clash.

2.3. THE ARCHITECT’S ROLE

Architects are well situated to moderate such conflicts for innovative solutions because they are involved with many of the stakeholders across the entire breadth of a school building project. Through the management of their design projects, they interact with many of the stakeholders and can inform others through such actions as participatory design and other predesign efforts. Through their design creativity they can offer innovative solutions for satisfying conflicting orders providing new pathways for safety in school design. Among those involved in the process of implementing a school building project it is likely that architects are best suited for moderating such conflicts. Understanding the various perspectives on ‘safety’ helps the architect to navigate competing orders and inform others of what drives their agendas. Helping to mediate differences provides for a better design project fulfilling more of the stakeholders’ needs and a better place to learn and grow. Rigorous research on safety and security issues provides the architect with the tools to help negotiate effective solutions.

3. DESIGN RESEARCH ON SCHOOL SAFETY AND SECURITY

3.1. WHY IS DESIGN IMPORTANT FOR SCHOOL SAFETY?

There are many reasons why safety and security research are important to the field of architecture. Firstly, we know that design and manipulation of the

environment has an impact on human behavior (Kopeck 2006; Bechtel 1997). Research shows that design has significant effects on academic performance. Tanner (2009) finds that variations in movement and circulation patterns significantly influence reading comprehension, language arts, mathematics, and science scores. Patterns of views significantly influence reading vocabulary, language arts, and mathematics. Wolhill and Van Vliet (1985), as cited by Tanner (2009), find a relationship between crowded learning spaces and student outcomes. Physical comfort factors of a school design can be positively or negatively correlated with performance, but other factors of design, which Schabmann et al. (2016) have deemed symbolic conditions, may as well. These symbolic conditions include overall appearance, classroom layout, objects, décor, complexity, and a variety of activities occurring within a space.

Crime Prevention Through Environmental Design (CPTED) has had mixed results in terms of associating the design of space (architectural, urban, and landscape) with reduction in crime (Taylor 2002), however, there is research that supports the assertion that design can remove opportunity for illicit behavior. Much empirical evidence exists on the design-crime link, and according to Taylor (2002), the theoretical bases for CPTED lies in a rational offender perspective, a behavioral geography perspective, and a routine activities perspective. A main insight developed by Lamoreaux (2017) is the link between CPTED strategies and the psychological wellbeing of students. Citing Skiba et al. (2004), Lamoreaux indicates that "Based on current findings, school connectedness and positive climate may contribute to school safety as much as physical security measures do" (27).

The notion that design can negatively affect behavior is supported by Fram and Dickmann (2012), who conclude that if a tendency for bullying and peer harassment is present, then that behavior can be exacerbated by specific elements of the built environment. They argue that the built environment can be a contributing factor in a school's bullying problem. Per Astor and Meyer (1999), "A recent study conducted by the authors of this article suggested that violence involving females in schools occurred in predictable school locations, at predictable times of the day, and with predictable sets of social circumstances associated with the school setting" (201-202).

School spaces can develop patterns of behavior associated with bullying, harassment, assault, theft, smoking, etc. Safety extends beyond the exceptionally rare events of mass shootings and is most affected by occurrences that impact every school, every day. If schools are to be thriving, viable places, they

must do more than provide protection from fire and earthquakes. They must be places where children find connectedness, a sense of belonging, and freedom from abuse or harassment.

Secondly, lack of academic research inhibits architects' abilities to make sound, science-backed decisions and this prevents them from possessing the necessary knowledge-base or data needed to support those decisions when challenged by stakeholders. As Thomas Fisher (2017) of the University of Minnesota notes, "Research has become critical to twenty-first century architectural practice. The more unanswered questions we have regarding the rapidly evolving world around us, the more we need research to help us answer them" (131).

Fisher (2017) also states that "Research leads to generalizable results that pertain to more than one instance or setting" (132).

Thirdly, there is great social and political pressure to reduce school violence. Many opinions and theories exist about the causes of violence in schools. Other fields such as education, psychology, and criminology are conducting the bulk of the research found in this literature review, and those findings are being applied to change educational practice. Solid research can potentially reduce knee-jerk reactions and decision-making that erodes civil liberties such as Second, Fourth, and Sixth Amendment rights.

Lastly, there is a call from both the state (federal and state governments) and the professions to conduct rigorous research on school safety and security. A recent legislative proposal, the School Safety Clearinghouse Act (S.2530 2019), hereafter referred to as The Act, calls upon institutions of higher education and design schools for input, and seeks "well-designed and well-implemented experimental study" (4).

Outside of academia, professional working groups such as the American Institute of Architects' (AIA) Committee on Architecture in Education (CAE) gather to discuss best practices and innovations in learning environment design (AIA 2019). The American Society of Industrial Security's (ASIS) School Security and Safety Council (SSSC) and the Security in Architecture and Engineering Council (SAEC) work to educate building owners, facility managers, and design professionals how to create safer learning environments (FSD 2020). The Association for Learning Environments (A4LE) also strives to improve best practices through its efforts in annual conferences. The Education Market Association trade group (EDmarket 2020), representing manufacturers, distributors, and service providers in education, also work towards providing solutions to safety and security problems. Both the A4LE and EDmarket groups work with the AIA to jointly educate

AIA members in designing better learning environments (Ed-Spaces 2018; LearningSCAPES 2019). The CAE publishes the research journal, *Dialogues* (CAE 2017), that addresses numerous topics related to school performance and the articles contained within do cite other peer-reviewed research. However, concerning school safety and security, none of the fourteen articles contained within the three annual publications addresses this topic.

3.2. HOW CAN ARCHITECTS RESPOND TO THE PROPOSED SCHOOL SAFETY CLEARINGHOUSE ACT?

The Act (S.2530 2019), mentioned above, directly challenges the architecture profession to contribute or recommend best practices in school design. The stated purpose of this Act is to require the Secretary of Homeland Security to establish a School Safety Clearinghouse. This clearinghouse would act in part as a central hub for best practices and case studies, review school safety recommendations by design professionals, and seeks to partner with organizations such as the AIA to provide training and technical assistance. This Act recognizes the importance of the architecture profession and the design schools in helping to solve the problems of bullying and violence within our schools. If enacted, schools of architecture would have a new avenue for grants to conduct cutting edge research in a neglected field of study.

4. A REVIEW OF SCHOOL SAFETY & SECURITY LITERATURE

4.1. IDENTIFYING INTERESTED STAKEHOLDERS

This research seeks to determine which stakeholders in society are most actively researching issues of school safety and security by searching available literature for the prevalence of subjects as defined by the nature of the journals in which these articles or books appear. The literature search aims to identify and collect as many relevant articles and books that specifically use the term 'safe schools', 'school safety', 'school security', and 'school shootings'. An examination of the journal titles will reveal in which fields discussions are occurring.

4.2. METHODOLOGY

The four terms of 'safe schools', 'school safety', 'school security', and 'school shootings' were searched within the Penn State University library's online system, which allows for searches of electronic resources available to students, including databases based on discipline such as architecture, criminal justice, education, etc. On the advice of a university librarian, I searched databases relevant to the issues of school safety or security. This

process produces reference lists for each search term, and each list is exported for later use in EndNote, a reference management software. Each database's search results are saved as individual files labeled according to the search term. Many databases are excluded for lack of relevance. In total there are sixty-seven relevant databases. Under each search term and relevant database, results are identified. The numbers in Table 2 below represent the number of useful or relevant articles within the total number provided by the search engine for both peer-reviewed/academic and non-peer reviewed/non-academic sources. For example, within the Art Full Text & Art Index Retrospective database, under the search term "School Safety", only three of the twenty-seven article results provided are relevant to the discussion.

Reasons for irrelevance include a different application or definition of the term safety. My research involves the mitigation of violence in school settings, so an example of irrelevance might be an article about laboratory safety, sports injuries, or bus transportation safety. Also, databases contain key phrases hidden within metadata that may not be located within the articles themselves, making them irrelevant. What is determined to be relevant is admittedly subjective as many of the databases have different options available for inclusion and have their own algorithms for inclusion. Some databases are excluded for lack of any filtering capabilities, making the task of identifying relevant articles overly burdensome.

The literature review is generally conducted according to a methodology developed by Warnes (2018) in his research paper entitled *Conducting a Literature Review Using NVivo*. Warnes developed his method as part of his literature review for his Ph.D. research on concepts of 'teaching excellence'. NVivo is a qualitative data analysis (QDA) computer software program produced by QSR International. It is designed to analyze mixed-methods data and can be used to find patterns across multiple media and sources. Researchers can encode text within articles and deep analysis allows a researcher to find patterns within articles, books, interviews, etc. to help discover gaps in research. Warnes (2018, 3-4) developed the following ten stages in his research paper:

- Stage 1: Searching
- Stage 2: Coding (reference lists)
- Stage 3: Tidying
- Stage 4: Sorting
- Stage 5: Collecting
- Stage 6: Categorizing
- Stage 7: Naming
- Stage 8: Cross-Referencing
- Stage 9: Thematic Coding
- Stage 10: Meta-Analysis

Each term is searched within the databases in advanced search mode using the exact phrases listed. The searches are limited to most recent research (2009-2019). Search results are limited to peer-reviewed when the option is available, so that it only reflects academic work to gain an understanding of the prioritization of these terms in academia. Searches are filtered for English-language only, and, where possible, limited to the geographic area of the United States.

Articles for inclusion are limited to those with the specific term in the title or the abstract. Searches for the terms anywhere in the text are avoided to prevent inclusion of an article that substantially addresses a different subject, but may include the term in an unrelated way. Each database provides a varying number of results. These are manually scanned for relevance. This scanning is somewhat subjective and often based on intuition or filtering where automatic filtering may have failed to omit unwanted results, such as articles outside the US. Using the web browser's "find" feature quickly identifies search terms within titles and abstracts. Not all articles have abstracts available for review.

Searching for these four terms presents some issues. Many of the database providers, such as ProQuest, have multiple databases available within them. For example, there are the ProQuest ERIC and ProQuest PsychArticles databases, which simply divide articles into different topics, but were also included in the all-encompassing ProQuest search. Independent searches within each individual database helps provide as many directions from which to find the relevant literature. There is a great deal of overlap between databases and duplicate articles are deleted. The process of deletion is based upon retaining as much bibliographic information as possible and identical articles with DOI numbers and abstracts were prioritized for search capabilities and for convenience of gathering articles for future analysis. Not all articles are able to be downloaded through the university or inter-library loan system. Results of the collection and filtering processes are shown in Table 1.

Once Adobe Acrobat PDF files of the articles/books are collected, they are renamed according to a convention suggested by Warnes (2018). This is: date_year_filename.pdf. The file naming conventions provided

by the databases vary greatly so this process makes articles easier to retrieve for analysis. These files are then imported into NVivo for a cursory analysis of the specific search terms in titles, abstracts, and associated PDF files. Here the search of the four terms is expanded to include text within the associated PDF files. This may present a methodology problem as the database filtering is limited to titles only, and then expanded to all content within those limited number of references. The purpose of the initial filtering is to reduce the references to only those whose authors deemed the search terms important enough to include within titles or abstracts. Given the approximately 2,700 articles referenced after duplicates are omitted, collection of PDFs requires significant time. Further analysis of this methodology is prudent. The types of journals and the top twenty most frequent words of six letters or more found in all documents, titles, and abstracts are identified. Figures for each search term are shown in table 2 below, and the resulting frequency of words and journal titles are found in figures 1 through 8.

4.3. RESULTS

This paper is intended to serve as a launching point for a literature review of the academic work involving the concepts of school safety and security, as part of my Ph.D. dissertation in how design might be a mitigating factor for school violence, a poor school climate, and lower academic performance. In order to identify gaps within the literature, and more specifically where the architecture profession and design schools might conduct research on an important social phenomenon, the first stage is to gain a sense of contemporary research, and what the role of architecture might be. Table 2 represents the results of the search.

	Search Term			
	"Safe Schools"	"School Safety"	"School Security"	"School Shootings"
Initial total references	717	2164	584	1296
After duplicate references removed	589	1045	367	731
References with search term in title only	39	133	45	117
Articles collected for analysis	33	99	29	85

Table 1: Reference Search and Duplicate Article Deletion Results. Source: (Author 2020)

Subject/Field	Database	Search Term							
		"Safe Schools"		"School Safety"		"School Security"		"School Shootings"	
		PR/A	NPR/NA	PR/A	NPR/NA	PR/A	NPR/NA	PR/A	NPR/NA
Art and Architecture	Art Full Text & Art Index Retrospective	2/6	10/26	3/27	12/14	0/0	6/6	0/0	12/47
	Avery Index	0/0	0/0	0/0	0/0	0/0	1/1	0/0	0/0
	EBSCO-Film & Television	0/1	1/1	0/0	1/1	0/0	2/2	3/4	38/38
	EBSCO-Arts & Humanities Index	1/1	0/0	1/4	0/0	0/0	0/14	8/8	8/12
	Taylor & Francis – Arts	1/5	□	6/8	□	0/4	□	6/33	□
	Taylor & Francis – Built Environment	3/5	□	3/10	□	2/3	□	0/1	□
Criminal Justice	Web of Science Arts & Humanities	0/1	□	1/2	□	0/0	□	3/4	□
	Annual Reviews	1/2	□	1/3	□	1/3	□	1/3	□
	Congressional Research Service Reports (CRS)	0/0	89	6/8	218,810	1/1	270,101	1/1	7,406
	CQ Researcher	1/8	□	7/11	□	3/15	□	9/22	□
	EBSCO Academic Search Complete	6/7	34/56	31/74	121/121	12/17	73/73	18/29	149/149
	EBSCO-Criminal Justice Abstracts	29/49	2/2	4/5	81/122	11/22	66/90	10/16	46/71
	PolicyFile	□□	0/3	□□	13/14	□□	1/1	□□	3/3
	ProQuest Doctoral Dissertation	1/1	□	47/110	□	18/18	□	12/14	□
Education	JSTOR - Education	49/245		88/403		38/95		11/294	
	ProQuest-ERIC	39/39	28	145/147	424	28/28	75	54/61	7
	ProQuest PsychArticles	1/1	□	7/7	□	0/0	□	2/4	□
	Sage Research Methods	4/9	□□□	7/18	□□□	1/2	□□□	8/24	□□□
	Sage Knowledge	□□	39/89	□□	99/185	□□	36/128	□□	125/381
	Taylor & Francis – Education	10/11	□	80/499	□	19/86	□	31/176	□
	EBSCO-ERIC	21/25	0/0	95/100	0/0	30/32	0/0	38/44	0/0
	Security Issues	8/18	□	15/37	□	14/21	□	19/66	□
Security Issues	Homeland Security Digital Library (HSDL) - Theses and Research reports	8/18	□	15/37	□	14/21	□	19/66	□
	HSDL - Journals and Articles	□□□□	1/13	□□□□	6/38	□□□□	0/10	□□□□	4/37
	Praeger Security International	0/0	0/1	0/0	0/1	0/0	0/0	0/0	0/4
	ProQuest-Risk Abstracts	2/2	0/0	7/13	0/0	1/1	0/0	5/6	0/0
Law	HEIN Online	5/8	□	7/23	□	3/6	□	9/10	□
	EBSCO Host Legal Periodicals and Books	6/81	1/2	17/153	4/5	10/76	3/5	16/117	10/18
	ProQuest Regulatory Insight	□□	14/23	□□	5/71	□□	0/17	□□	0/12
	Philosophy	PhilPapers	□□□□	1/3	□□□□	0/4	□□□□	0/0	□□□□
Philosophy	Philosopher's Index	1/1	0/1	1/1	0/1	0/0	0/0	2/2	1/2
	EBSCO America History	0/0	0/3	2/4	0/0	0/0	0/0	5/12	1/2
	Gale Virtual Reference Library	5/5	219	35/35	109	8/8	26	50	159
	EBSCO-Peace Research	0/3	0/0	2/2	0/0	1/2	1/2	1/2	9/14
Political Science	Penn State Electronic Theses and Dissertations (Political Science)	0/1	□	1/1	□	1/1	□	3/4	□
	Web of Science (Political Science)	40/67	□	185/309	□	37/47	□	133/178	□
	ProQuest Dissertations and Theses (psychology only)	3/3	□	32/62	□	7/19	□	23/31	□
	ProQuest Nursing and Allied Health	95/132	11/22	182/277	44/46	23/37	3/3	106/145	1/1
Health	EBSCO-CINAHL	4/7	19/19	41/44	1/1	6/7	0/2	19/20	28/28
	EBSCO-Health & Psychosocial Instruments	0/0	□	0/0	□	0/0	□	0/0	□
	EBSCO-Health and Safety Science Abstracts	0/0	0/1	7/7	0/4	1/1	0/0	1/1	0/0

Designing 'Safe' Schools

Social Science	EBSCO- Race Relations	1/3	0/0	12/12	0/0	7/7	0/0	1/3	0/0
	ProQuest (all databases)	0/3	2,367	88/355	16,694	28/46	4,238	6/10	9,975
	ProQuest Sociological Abstracts	2/2	2/2	67/129	1/1	6/8	1/1	3/4	0/1
	Social Sciences Citation Index	□□	25/38	□□	215/279	□□	/3544	□□ 80/128	90/137
Structural Design/ Construction Engineering Technology	EBSCO - Business Source Premier (Engineering)	5/10	5/5	14/27	/271	4/7	/138	23/37	/850
	Compendex- Engineering Village 2	2/12	0/0	1/4	0/0	5/11	0/14	8/13	8/12
	ProQuest-Dissertations & Theses A&I	1/1	□	4/14	□	1/1	□	1/3	□
	Taylor & Francis – Engineering and Technology	2/11	□	0/31	□	2/4	□	0/3	□
Women's, Gender & Sexual Studies	JSTOR-Feminist, Gender, and Women's Studies	□	2/5	□	5/10	□	0/1	□	6/8
	LGBT Thought & Culture	□	0/0	□	0/0	□	0/0	□	0/0
	EBSCO-LGBT Life	12/13	31/32	8/9	15/16	0/0	2/2	0/0	6/6
	EBSCO-Women's Studies International	0/1	1/1	3/4	1/1	0/0	0/0	8/12	1/1
American Studies	EBSCO-Communication & Mass Media	0/1	0/0	3/5	4/4	0/0	2/2	5/6	2/9
	JSTOR-American Studies	□	2/2	□	5/5	□	0/0	□	7/7
Business & Economics	ABI/INFORM	0/2	11/12	22/28	225/227	2/2	76/76	1/1	247/247
	Business Source Premier	2/3	5/5	22/28	23/23	2/2	17/17	1/1	56/133
	EBSCO-EconLit	□□	0/0	□□	3/3	□□	0/0	□□	2/2
History	EBSCO-American History and Life	0/0	0/0	3/4	0/0	0/0	0/0	2/2	1/2
	EBSCO-Historical Abstracts	0/0	0/0	1/2	0/0	0/0	0/0	2/4	0/0
Misc./ General	Brill Online Books and Journals	□□	0/0	□□	0/0	□□	0/0	□□	0/0
	EBSCO-Academic Search Alumni	4/5	13/13	16/23	108/108	8/8	68/68	28/32	145/145
	EBSCO-Ageline	0/0	0/0	1/1	0/0	0/0	0/0	0/0	0/0
	EBSCO-Anthropology Plus	□□	0/0	□□	0/1	□□	0/4	□□	0/1
	EBSCO-eBook Collection	0/0	1/1	0/0	2/2	0/0	0/0	0/0	0/1
	EBSCO-GeoRef	0/0	0/0	0/1	0/0	0/0	0/0	0/0	0/0
	EBSCO-GeoRef in Process	0/0	0/0	0/1	0/2	0/0	0/0	0/0	0/0
	EBSCO-Library, Literature, and Information Science Index	0/0	0/0	0/0	1/1	0/0	0/0	1/1	11/14
	EBSCO-Library, Information Science, & Technology Abstracts	0/0	0/0	1/1	2/2	0/1	1/2	1/1	14/17
	EBSCO-MLA International Bibliography	0/0	0/0	1/1	0/0	0/0	0/0	2/2	0/0
	EBSCO-Open Dissertation	2/9	□	34/54	□	4/4	□	18/24	□
	Scopus	□□	111/112	□□	236/236	□□	49/49	□□	199/223
Environmental	EBSCO-GreenFILE	0/2	0/0	1/1	2/2	1/1	0/0	0/0	1/1

□	Non-academic or non-peer reviewed sources are unavailable.
□□	Peer-reviewed option is unavailable.
□□□	Peer-reviewed option is unavailable, but results are peer-viewed or in an academic journal.
□□□□	Some content is peer-reviewed.
PR/A	Peer-reviewed or found in academic literature.
NPR/NA	Non-Peer Reviewed or non-academic.

Table 2: Database Search - Relevant results per total search hits returned. Source: (Author 2020)

A search for most common words contained within found articles, under each search term, shows the following:

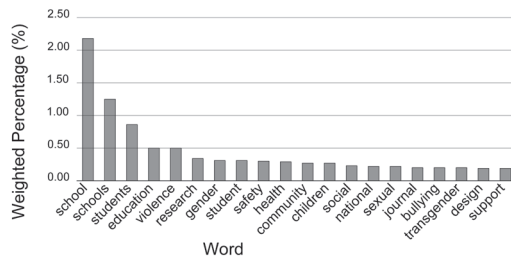


Figure 1: Twenty most frequent words found within titles, abstracts, and bodies of 'Safe Schools' literature reviewed. (Author 2020)

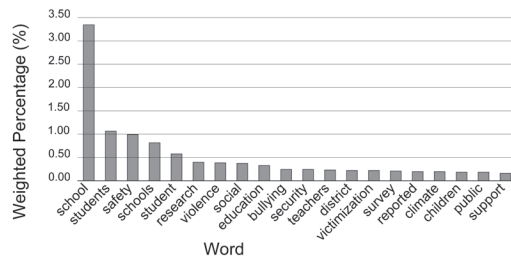


Figure 2: Twenty most frequent words found within titles, abstracts, and bodies of 'School Safety' literature reviewed. (Author 2020)

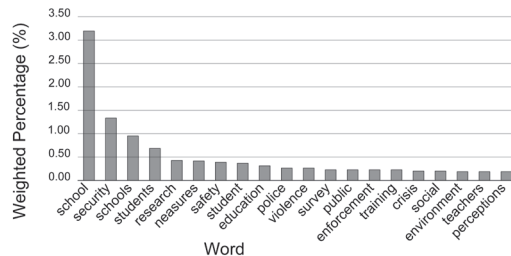


Figure 3: Twenty most frequent words found within titles, abstracts, and bodies of 'School Security' literature reviewed. (Author 2020)

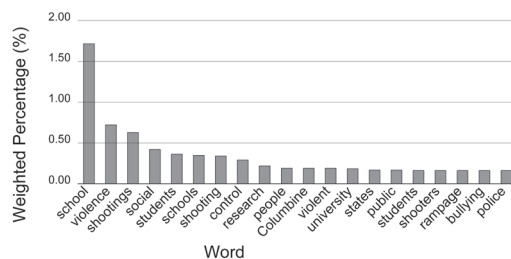


Figure 4: Twenty most frequent words found within titles, abstracts, and bodies of 'School Shootings' literature reviewed. (Author 2020)

Under all four search terms the word design is absent except for "safe schools", where it ranks 19th.

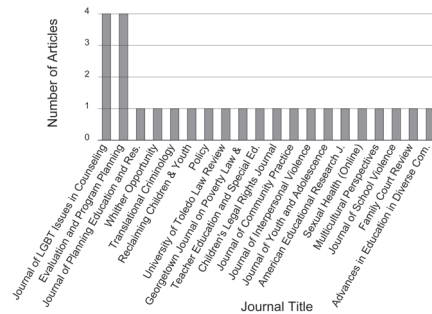


Figure 5: Most frequent journals containing the term 'Safe Schools' in the literature reviewed. Source: (Author 2020)

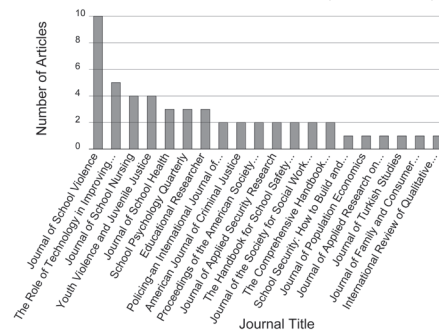


Figure 6: Most frequent journals containing the term 'School Safety' in the literature reviewed. Source: (Author 2020)

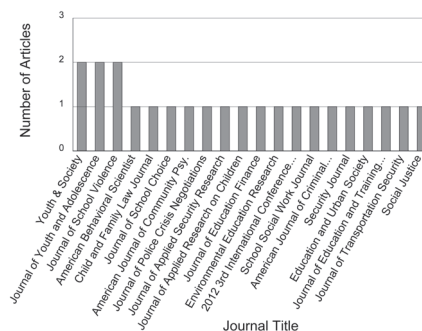


Figure 7: Most frequent journals containing the term 'School Security' in the literature reviewed. Source: (Author 2020)

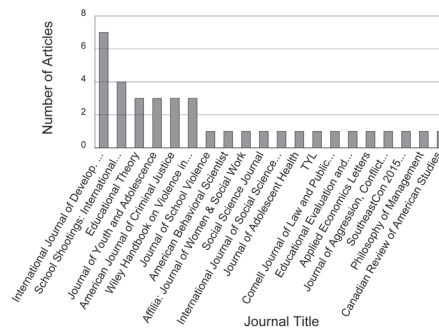


Figure 8: Most frequent journals containing the term 'School Shootings' in the literature reviewed. Source: (Author 2020)

The most frequent journal titles found in the literature review, identified in figures 5-8, illustrate that the predominance of school safety and security research is unrelated to design or architecture. Given the call for more research from within the profession, this is surprising. What is evident is the difference between academic and non-academic writing. Non-academic professional journals in architecture containing articles about safety and security include *Architectural Record*, *Architect*, *Architectural Design*, *Domus*, and the *RIBA Journal*. Sample articles include *Safe Havens* (Logan 2017), *Tackling Safety Through Design* (Kaiser 2013), and *The Need to Lead in School Design* (Cimino 2018). While these articles discuss the seriousness and desire to solve the problems related to the issue, they do not cite any research that serves as a foundation for prudent decision making. The trade and professional articles generally reflect consensus opinion or common practice within the profession. Outside of architecture, journals include *Landscape Architecture*, *Art Newspaper*, *Arts in Psychotherapy*, and *International Design*. Trade journals including *Security Design Management (ASIS)*, *Entertainment Up-Close*, and *Tech & Learning* have written about issues of school safety and security.

CONCLUSION

What is evident from this literature search is that the academic field of architecture is not conducting research on issues of safety and security in school environments, as other fields are. Fields, such as psychology, gender studies, education, and criminology, address safety and security from a broad and holistic perspective. Within psychology research, the role of architecture in the safety and security of school environments has been explored (Lamoreaux 2017). This research supports the impact architecture has on the psychology of those who occupy the spaces we design. Research by Walton (2011) in the field of education addresses physical design in safe school environments. Given that approximately 20% of the US population is in a school each weekday, it is prudent to conduct research on such spaces and the impact design has on school safety and security. Moore and Lackney (1993) have investigated a rethinking of the design of learning spaces in order to improve a sense of community and improving school climates. Practitioners such as Nair (2017) have promoted new approaches to the design of learning spaces arguing, "School building design can be a very significant and often overlooked force in creating a positive school climate" (13). As Scott-Webber (2004) notes, "The large body of environment/behavior research affirms the importance of the relationship between human behavior

and the physical environment, it enables the production of environments supporting intended behaviors, and defines major components of these behaviors" (5).

The literature review reveals that stakeholders who desire to keep schools safe are overwhelmingly non-designers. If the design of the built environment has an impact on people's physical and psychological wellbeing, then wouldn't architects have useful input in the research of how to design school spaces so that they may become safer places to learn? Given the vast number of financial resources devoted to keeping schools safe, sound research on how the design of a school can impact safety is warranted so that the negative effects of certain interventions don't dominate (technological such as: surveillance or metal detectors and human such as armed school resource officers or armed teachers). Much effort is put into these non-architectural strategies with little to no empirical data to support such efforts. On the contrary, many of these solutions have shown to negatively impact learning.

Future useful research on this topic might include: completion of Warnes (2018) methodology for deep analysis of the collected articles, a closer examination of the non-academic literature to determine where attention is centered and a closer look at why schools of architecture are not emphasizing the environment-behavior connection within their curricula through the provision of either core courses or electives. A review of NAAB accredited programs by this author reveals that only 13.7% architecture schools provide an environment-behavior related course within their school, in various degree programs such as architecture, interior design, or environmental design; of the 138 accredited schools examined, only 7.2% offered an environmental psychology course.

Architectural research into safer and more secure school design can provide the basis that affords architects the ability to help school administrators make the right decisions. When we think about the various stakeholders and the institutional logics behind why and how they attempt to achieve the same goal, empirical data can bridge the gap between differing opinions. School board members are beholden to those who vote for them, law enforcement officers to their professional sense of duty, school counselors to the students they guide, and architects to a sense of professional ethics, duty, and desire to make a profit. With adequate research to support the work, an architect can navigate disagreements and unsubstantiated opinions in search of compromise and even innovation. Research arms the architect against stakeholders whose tradition, opinion, and motivations are driven by their own particular institutional logics. Research also allows for innovation as friction between logics has often led to changes

in the building code providing owners, contractors, occupants, and code officials what they request, but from a new direction.

Safety and security in school environments requires the architecture field become an active participant ensuring the betterment of students'

experiences and academic development. Given the lack of architectural research shown above, and the desire by political leaders and the architecture profession to work on real evidence-based solutions, there is an opportunity for the design schools to pave the way for valuable research.

REFERENCES

- A4LE (Association for Learning Environments). 2020. "Mission and Vision". Accessed February 9, 2020. <https://www.a4le.org/A4LE/About/A4LE/About/About.aspx>
- AIA (American Institute of Architects). 2019. *Conference Report - The Design of Safe, Secure & Welcoming Learning Environments: Hosted by the Committee on Architecture for Education*. Accessed February 9, 2020. http://content.aia.org/sites/default/files/2019-09/CAE_Report_v7_FINAL_interactive.pdf
- Astor, R. A., N. Guerra, and R. Van Acker. 2010. "How Can We Improve School Safety Research?" *Educational Researcher* 39, no.1: 69-78. <http://dx.doi.org/10.3102/0013189X09357619>
- Astor, R. A. and H.A. Meyer. 1999. "Where Girls and Women Won't Go: Female Students', Teachers', and Social Workers' Views of School Safety." *Children & Schools* 21, no. 4: 201-219. doi:10.1093/cs/21.4.201
- Bechtel, Robert B. 1997. *Environment & Behavior: An Introduction*. Thousand Oaks: Sage Publications.
- Berg Johansen, C., and S.B. Walldorff. 2015. "What are Institutional Logics-and Where is the Perspective Taking Us?" *Academy of Management Proceedings* 2015, no. 1, 14380. Briarcliff Manor, NY 10510: Academy of Management. DOI:10.5465/ambpp.2015.14380abstract
- Bucher, K. T. and M.L. Manning. 2005. "Creating Safe Schools." *The Clearing House: A Journal of Educational Strategies, Issues and Ideas* 79, no.1: 55-60. DOI:10.3200/TCHS.79.1.55-60
- CAE (Committee on Architecture in Education). 2017. "Dialogues." Accessed February 9, 2020. <https://pubs.royle.com/view/designquest-media/learning-by-design/dialogues-fall-2017>
- Cimino, Steve. 2018. "The Need to Lead in School Design." *Architect* 107, no. 9: 73. <http://search.ebscohost.com.ezaccess.libraries.psu.edu/login.aspx?direct=true&db=buh&AN=133819904&site=ehost-live&scope=site>.
- Crowe, T. D., and National Crime Prevention Institute (University of Louisville). 2000. *Crime Prevention Through Environmental Design: Applications of Architectural Design and Space Management Concepts* (2nd ed.). Boston: Butterworth-Heinemann.
- "EDmarket: About Us." Education Market Association. Accessed February 9, 2020. <http://www.edmarket.org/aboutus/>
- "ED-Spaces: Architects, Designers, Facility Planners & Professional Firms." ED-Spaces 2018. <http://www.ed-spaces.com/attendees/architects-designers/>
- "Facility Security Design (FSD)." ASIS International. Accessed February 09, 2020. <https://www.aEsonline.org/professional-development/asis-contract-learning/facility-security-design/>
- Fram, S. M. and E.M. Dickmann. 2012. "How the School Built Environment Exacerbates Bullying and Peer Harassment." *Children, Youth and Environments* 22, no. 1: 227-49. doi:10.7721/chilyoutenvi.22.1.0227.
- Fisher, Thomas. 2017. "Research and Architecture's Knowledge Loop." *Technology/Architecture + Design* 1, no. 2: 131-134. doi:10.1080/024751448.2017.1354601
- Friedland, R. and R. Alford. 1991. "Bringing Society Back In: Symbols, Practices, and Institutional Contradictions." In *The New Institutionalism in Organizational Analysis*, edited by W. Powell, & P. Dimaggio, 232-263. Chicago: University of Chicago Press.
- Gastic, B. 2011. "Metal Detectors and Feeling Safe at School." *Education and Urban Society* 43, no. 4: 486-498. DOI:10.1177/0013124510380717
- Hankin, A., M. Hertz, and T. Simon. 2011. "Impacts of Metal Detector Use in Schools: Insights From 15 Years of Research." *Journal of School Health* 81, no.2: 100-106. DOI:10.1111/j.1746-1561.2010.00566.x
- Jeffery, C. R. 1971. *Crime Prevention Through Environmental Design*. Beverly Hills: Sage Publications.
- Kopec, D. A. (2006). *Environmental Psychology for Design*. New York: Fairchild Publications Inc.
- Lamoreaux, D. 2017. "Student Preferences for Safe and Psychologically Comfortable School Facilities." PhD diss., University of Arizona. <https://repository.arizona.edu/handle/10150/626658>
- LearningSCAPES 2019. "Electronic Conference Program." Accessed February 09, 2020. <https://learningscapes2019.a4le.org/program/mobile/index.html>

Designing 'Safe' Schools

- Logan, Katharine. 2017. "Safe Havens." *Architectural Record* 205, no. 1: 112–18. <http://search.ebscohost.com.ezaccess.libraries.psu.edu/login.aspx?direct=true&db=buh&AN=120637830&site=ehost-live&scope=site>.
- Kaiser, Laura Fisher. 2013. "Tackling Safety Through Design." *Architectural Record* 201, no. 3: 38. <http://search.ebscohost.com.ezaccess.libraries.psu.edu/login.aspx?direct=true&db=buh&AN=86453826&site=ehost-live&scope=site>.
- Mayer, M. J. and M.J. Furlong. 2010. "How Safe Are Our Schools?" *Educational Researcher* 39, no.1: 16-26. <http://dx.doi.org/10.3102/0013189X09357617>
- Moore, G. T., and J.A. Lackney. 1993. "Design Patterns for American Schools: Responding to the Reform Movement." Accessed October 3, 2019. <https://eric.ed.gov/?id=ED375515>
- Nair, P 2017. *Blueprint for Tomorrow: Redesigning Schools for Student-Centered Learning*. Cambridge: Harvard Education Press.
- Newman, Oscar. 1973. *Defensible Space: Crime Prevention through Urban Design*. New York: Collier Books.
- Perumean-Chaney, Suzanne and Lindsay M. Sutton. 2013. "Students and Perceived School Safety: The Impact of School Security Measures." *American Journal of Criminal Justice: AJCJ* 38, no. 4 (December): 570-588. <https://doi.org/10.1007/s12103-012-9182-2>
- Safe Schools Clearinghouse Act, S.2530, 116th Cong. (2019). <https://www.congress.gov/116/bills/s2530/BILLS-116s2530is.pdf>
- Schabmann, A., V. Popper, B.M. Schmidt, C. Kühn, U. Pitro, and C. Spiel. 2016. "The Relevance of Innovative School Architecture for School Principals." *School Leadership & Management* 36, no. 2: 184-203. <https://doi.org/10.1080/13632434.2016.1196175>
- Schreck, Christopher J. and J. Mitchell Miller. 2003. "Sources of Fear of Crime at School: What is the Relative Contribution of Disorder, Individual Characteristics, and School Security?" *Journal of School Violence* 2, no. 4: 57-79. DOI: 10.1300/J202v02n04_04
- Scott-Webber, Lennie. 2004. *In Sync: Environmental Behavior Research and the Design of Learning Spaces*. Ann Arbor: Society for College and University Planning.
- "security, n." OED Online. December 2019. Oxford University Press. <https://www-oed-com.ezaccess.libraries.psu.edu/view/Entry/174661?redirectedFrom=security> (accessed February 09, 2020).
- Skiba, R., A.B. Simmons, R. Peterson, J. McKelvey, S. Forde, and S. Gallini. 2004. "Beyond Guns, Drugs and Gangs: The Structure of Student Perceptions of School Safety". *Journal of School Violence* 3, No. 2: 149-171. DOI:10.1300/J202v03n02_09
- Tanner, C. K. 2009. "Effects of School Design on Student Outcomes." *Journal of Educational Administration* 47, no. 3: 381-399. DOI:10.1108/09578230910955809
- Taylor, Ralph B. 2002. "Crime Prevention Through Environmental Design (CPTED)." In *Handbook of Environmental Psychology*, edited by Robert B. Bechtel and Arza Churchman, 413-426. New York: John Wiley & Sons, Inc.
- Thornton, P. H., W. Ocasio, and M. Lounsbury. 2012. *The Institutional Logics Perspective: A New Approach to Culture, Structure and Process*. Oxford: Oxford University Press.
- Walton, R. H. 2011. "Physical Designs for Safe Schools." PhD diss., Virginia Tech. <https://vtechworks.lib.vt.edu/handle/10919/40397>
- Warnes, M. 2018. *Conducting a Literature Review using NVivo*. ResearchGate. https://www.researchgate.net/publication/327117399_Conducting_a_Literature_Review_using_NVivo. DOI 10.13140/RG.2.2.31849.75360
- Wohlwill, J. F. and W. van Vliet. 1985. *Habitats for Children: The Impact of Density*. Hillsdale, N.J: L. Erlbaum Associates.

A PROLEGOMENON TO IMAGE-BASED HISTORIOGRAPHY: Forensic Architecture's Spatiotemporal Model and the Split-Second Event

Nicholas Andrew Pacula
Yale University

Abstract: This paper looks to the investigatory work of Forensic Architecture as a model for new practices of architecture historiography. Departing from architecture history's long-standing familiarity with events corresponding to long histories, this paper investigates the split-second event and the media platforms that mobilize it. A close reading of a series of video-stills taken from Forensic Architecture's video-based spatiotemporal investigations reveals that contemporary media has reconditioned our perception of the duration of historical events, as well as the spaces in which these events are thought to have occurred. Beginning with an outline of Forensic Architecture's spatiotemporal model and the historical narratives it produces, this paper subsequently traces Forensic Architecture's most recent investigations to eighteenth-century precedents, making evident a historical progression toward increasingly higher "thresholds of detectability." The emergence of a "forensic aesthetics" in the mid-1980s is then read as the seed of a historiographic rhetoric concerned with densifying and diversifying medias and the platforms facilitating their circulation. Finally, Forensic Architecture's investigatory work is understood as producing historical narratives in which historiographic methods that routinely differentiate between speaker, content, and reference are eclipsed, offering instead near-seamless continuity and an emergent opportunity to witness history speak for the events and objects under its gaze.

Keywords: Historiography, Forensic Architecture, media, evidence, method

INTRODUCTION

The making of facts, then, depends on a delicate aesthetic balance, on new images made possible by new technologies, not only changing in front of our very eyes, but changing our very eyes—affecting the way that we can see and comprehend things. Aesthetics, as the judgement of the senses, is what rearranges the field of options and their perceived likelihood and cuts through probability's economy of calculations. The word conviction thus articulates the legal verdict with the subjective sensation of confirmed belief, of being convinced (Keenan and Weizman 2012, 24).

Eyal Weizman's "Threshold of Detectability"

In the introduction to his 2017 book, *Forensic Architecture*, Eyal Weizman defines the "threshold of detectability" in relation to the maximum resolution of publicly available satellite imagery in the years between 2008 and 2014. Weizman defines this limit as the threshold at which figures depicted in satellite imagery can or cannot be identified. Given that one pixel typically equates to 50 cm of real measurement, things measuring greater than 50 cm by 50 cm can be detected but things measuring less cannot. Weizman is careful to point out that a person cannot be detected but something bigger, like a building or landscape, can.

In the pages that follow I would like to bring Weizman's concept of the threshold of detectability to bear upon what I identify as the *spatiotemporal*

models defining Forensic Architecture's investigational work.¹ I propose to do this by reorienting Weizman's definition of the threshold of detectability from being almost exclusively about satellite imagery and related issues of resolution and legibility towards a more general discussion about historiography and the media contributing to Forensic Architecture's projects. This reframing will allow me to speak about Forensic Architecture's practice as a unique model for historiographic inquiry with historical ties to ever-changing perceptions of the veracity of images.

Many of Forensic Architecture's more recent investigations are communicated via web-based videos², in which a 3D model depicting a built environment is used to carry various forms of primary- and secondary-source evidence. Video and audio recordings, models of both physical and digital kinds, witness testimony, simulations and timelines are all assembled in a way that yields a multi-sensory reading of an architectural environment. It might be said that Forensic Architecture writes—in the medium-non-specific sense—the biographies of the various objects factoring into their investigations. In a complimentary way, my intent is to use this paper as an opportunity to write the biography of the object made by Forensic Architecture: the web-based video investigation. If Forensic Architecture's work is understood as occurring within the rectilinear video frame, then my work looks

beyond this frame and aims to better contextualize Forensic Architecture's work as a historiographic model tuned toward emerging media through which scholarship can be both formulated and disseminated.

1. FORENSIC ARCHITECTURE'S SPATIOTEMPORAL MODEL

At the beginning of Forensic Architecture's investigations, a past event and a series of lingering questions surrounding that event are identified as the target or cause of the investigation. If not coincidentally, then shortly thereafter, Forensic Architecture reveals a digital 3D model representing the space in which the event took place. This model is a critical aspect of the investigation because it serves as the site in which both primary- and secondary-source evidence is located and subsequently read. To convince viewers of the fidelity of this model to the real-world space for which it is intended to speak, Forensic Architecture locates primary-source photographic images and video recordings on top of the 3D model in an effort to demonstrate continuity between the two forms of evidence (figure 1).



Figure 1: Still from 00:02:23 of Forensic Architecture's "Ali Enterprises Factory Fire" investigation. A photograph of the third-floor workspace of the Ali Enterprises Factory—destroyed by fire in 2012—has been laid over a 3D model of the same space. Continuity between the photograph and model may be seen where the edges of the photograph meet the 3D model space behind. (Forensic Architecture, 2018)



Figure 2: Still from 00:02:27 of Forensic Architecture's "Ali Enterprises Factory Fire" investigation. The photograph previously visible in figure 1 is no longer present, allowing a 3D model of the Ali Enterprises factory building to occupy the entire frame. (Forensic Architecture, 2018)

In Forensic Architecture's "Ali Enterprises Factory Fire" investigation, a critical moment in the argument comes when the 3D model must be accepted as an accurate reproduction of the burned-down building for which it is intended to speak. With this in mind, it may become evident why the photograph featured in figure 1 is not actually very important to Forensic Architecture's task of "uncover[ing] the many ways in which design and management decisions not only failed to prevent injury and casualties [250 people died in the fire], but in fact augmented the death toll" (Forensic Architecture 2018). The photograph we see laid over a grey-tone digital model in figure 1 does not provide novel information pertaining to the "design and management decisions" that may have "augmented the death toll." Rather, this photo says something about the remaining thirteen minutes of the video clip: that Forensic Architecture's 3D model may adequately speak for the building as it was before the fire, when the building was intact and undamaged. The photo's correspondence to structural aspects of the building, as well as furniture found in the model, helps convince a viewer that the entire model—not just the part visible in this single frame—is a faithful representation of the space for which it now speaks (figure 2).³ If this single photo of an interior space on the third floor of the Ali Enterprises factory building matches the 3D-modeled space immediately beyond its edge, then why should we not be convinced that the rest of the building's floors, its exterior and neighboring context—all featured in the ensuing video investigation—would also match available photographs?

As a rhetorical tool, the novelty of the 3D model is found in its functioning as a spatial entity binding together various kinds of historical evidence. Though we have only witnessed the correlation between a single photo of the building prior to the deadly fire overlaid upon a 3D model produced several years thereafter, this mode of argumentation is characteristic of the early stages of many of Forensic Architecture's investigations. What typically follows is a process of locating various kinds of historical evidence within the 3D model. In the case of the Ali Enterprises factory fire, low-resolution copies of photos taken during the initial investigation by local fire marshals, witness testimony, legal documents pre- and post-dating the event and speaking to local fire codes and the building's lack of appropriate infrastructure are all interrelated within the referenced 3D model of the architectural space.

If we can now see how the "spatio" component of Forensic Architecture's spatiotemporal model corresponds to a 3D model created after the event for which it is intended to speak and serves to hold evidence and relate it to a spatial environment,⁴ the presence of a timeline within these investigatory videos affords a complimentary purpose.

A timeline is defined as a graphic representation of the linear passage of time. When time is rendered as a line, an event may appear upon that line; identified by the specific moment at which it is believed to have taken place. This makes it so that multiple events may be ordered in sequence. Expressed another way, a timeline makes it possible to say that event 'x' happened before, during or simultaneous to event 'y' because of where events 'x' and 'y' appear on a timeline. Forensic Architecture often attempts to re-enact a past event, so it becomes necessary that they be able to chronologically order micro-events comprising a larger macro-event. For example, in the top area of figure 3 we see the timeline used to order the smaller micro-events comprising the Ali Enterprises factory fire: "the earliest

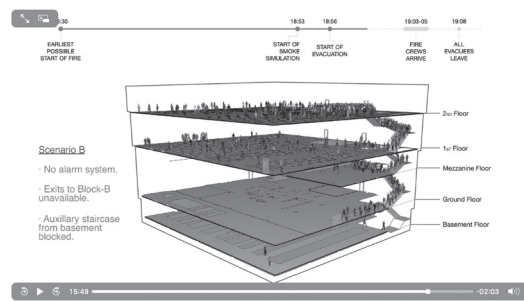


Figure 3: Still from 00:15:49 of Forensic Architecture's "Ali Enterprises Factory Fire" investigation. The timeline visible above the 3D model organizes the events comprising the building fire between 6:30pm and 7:08pm. (Forensic Architecture, 2018)



Figure 4: Still from 00:14:45 of Forensic Architecture's "Murder of Halit Yozgat" investigation. The timeline visible at the leftmost side of the frame plots the activities of five people in an internet café during the seven minutes between 4:57pm and 5:04pm. (Forensic Architecture, "The Murder of Halit Yozgat" 2019)

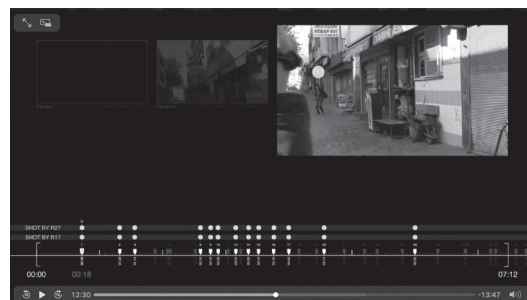


Figure 5: Still from 00:12:30 of Forensic Architecture's "Killing of Tahir Elci" investigation. The timeline visible in the bottom quarter of the frame plots the discharge of more than 40 bullets by seven different gunmen over a period of 7.12 seconds. (Forensic Architecture, "The Killing of Tahir Elci" 2019)

possible start of fire” precedes the “start of evacuation”, which in turn precedes the moment “fire crews arrive” and, later still, “all evacuees leave” the building.

When the timeline in figure 3 is read alongside other timelines featured in contemporaneous Forensic Architecture investigations (figures 4-5), we see something unique: Forensic Architecture is not dealing with typical historical timescales like the “period” (100 or more years) or “generation” (generally 30 years). Rather, they are dealing with “split-second” events taking place over the course of seconds, minutes, or hours.⁵ Events for which fractions of a second often matter in the parsing of micro-events like the evacuation of several hundred people from a burning building, the activities of five people in an internet café, or sustained gunfire from multiple sources.⁶ Additionally, these timelines serve to relate the evidentiary media speaking for the event to the media by which the investigation of the event is communicated. In other words, video and other digital (or digitized) evidence is narrativized in a web-based video with its own unique timeline, (refer to the media-player interface visible in the bottom portion of the screen in figures 3, 4, and 5, as an example). The timeline is thus as crucial to organizing the evidence pertaining to the event, as it is to organizing the medium through which the event will be communicated.

Perhaps we can now see how Forensic Architecture's spatiotemporal model holds the potential to add several new and intriguing potentials to the writing of history. The split-second event, the spatiotemporal model as a research-carrying tool, and the web-based video as a method for narrativizing this research all constitute novel approaches to traditional historiography. Having a good grasp on the types of investigations Forensic Architecture conducts and the kinds of models in which evidence is located and subsequently animated, we now turn to see how these investigations more generally relate to contemporary visual culture and other inquiries into the split-second event.

2. THE DEATHS OF CAPTAIN JAMES COOK AND TAHİR ELÇİ

Captain James Cook died in 1779. Tahir Elçi died in 2015. Four years after each event images speaking to the causes of these men's deaths would begin circulating. Let us juxtapose these two images: an eighteenth-century copperplate print, *Death of Captain Cook*, 1783 (figure 6) and a still-image from Forensic Architecture's web-based video investigation of "The Killing of Tahir Elçi," 2019 (figure 7).

First, we need to know a little about what is depicted in each image. In February 1779, the famed British sea captain James Cook returned to Hawaii's Kealahakua Bay just a few months after having departed



Figure 6: John Webber's *Death of Captain Cook*, 1783. The faintly visible engraved inscription reads, immediately below image at left, "Drawn by J[oh]n Webber"; below image at center, "T[h]e Figures engr[ave]d by Fra[nc]esco Bartolozzi"; below image at right, "The landscape by Will[iam] Byrne." (Yale Center for British Art)



Figure 7: Still from 00:08:23 of Forensic Architecture's "Killing of Tahir Elçi" investigation. The content in the video-recorded image at center and that of the 3D model behind it may be seen as continuous where the 3D-modeled red figure at right converges with the video recorded image featuring Elçi's head and left arm. Continuity is also visible where 3D-modelled storefronts behind the central figures merge with those of the video recording. (Forensic Architecture, "The Killing of Tahir Elçi" 2019)

due to a broken mast on one of the ships in his fleet. The Royal Academician and painter John Webber was aboard one of the ships in Cook's fleet when it returned to Kealakekua Bay. Although it is generally accepted that Webber did not personally witness the moment in which Cook was killed, Webber's assignment on Cook's third and final voyage was that of "topographical artist" tasked with "illustrating the official journey of the trip" ("The Death of Captain Cook" n.d.). In October 1780, more than a year after Cook's death, Webber returned to London where the British Admiralty commissioned him to produce finished drawings and engravings of what he had seen during his travels. In 1783 the London-based engravers Francesco Bartolozzi and William Byrne would produce the copperplate etching from which the print reproduced in figure 6 was first made.

If Cook was indeed killed upon returning to Kealakekua Bay in February 1779, it would be more than four years and at a navigable distance of more than 25,000 miles, before the institutionally authorized image depicting his death would be produced under the direction of a pre-determined witness.

The second image (figure 7) speaks to an event that occurred on November 28, 2015 when Tahir Elçi was fatally shot in Diyarbakir, Turkey. A Kurdish lawyer, Mr. Elçi was at the center of a press conference when two nearby gunmen "shot and killed two policemen . . . who approached the taxi in which they were traveling. They [the gunmen] leapt out of the vehicle and fled the scene" (*Open Democracy* 2019). The pair headed down Yenikapi Street, toward Elçi's press conference and, "as they approached the scene, at least five of the policemen present at the press conference [four with handheld video cameras] opened fire. In a little over nine seconds, forty shots were fired. The brief shootout ended with only one fatality: Elçi. . . ." (*Open Democracy* 2019). "In 2016, the Diyarbakir Bar Association, of which Elçi was chairman at the time of his death, asked Forensic Architecture to examine the evidence in their possession, and to independently investigate the circumstances of his death" (Forensic Architecture, "The Killing of Tahir Elçi" 2019). The evidence factoring into Forensic Architecture's investigation, and located within a spatiotemporal model, was primarily limited to video recordings produced at the time of the shooting.

We might now ask: what is the threshold of detectability for each of the two images? In the still image excerpted from "The Killing of Tahir Elçi" we must remember that we are looking at a single frame from a twenty-six-minute-long video outputting thirty frames per second. We must also remember that the still image depicted at the very center of figure 7 belongs to primary-source video embedded within the video investigation, and has been sourced from one camera perspective among three others that captured video at the time of Elçi's killing. All together, these four cameras initially produced sequences of still images at a rate of twenty-five images per second. This means that the "nine seconds and ten frames" Forensic Architecture identifies as the duration of this event, considered in conjunction with the footage from four cameras capturing still images at a rate of 25 per second, yields 100 still images produced each second, and a total of 940 distinct images for the duration of the event identified as the killing of Tahir Elçi (Forensic Architecture, "The Killing of Tahir Elçi" 2019). Conversely, the image said to depict the death of Captain Cook is a print made from a copperplate etching produced by two London-based engravers, Francesco Bartolozzi and William Byrne, upon both visual and verbal instruction

from the institutionally-authorized witness, John Webber, who, four years prior, indirectly witnessed an act of violence that resulted in Cook's death.

Indeed, it would be difficult to argue that one of the images reproduced in figures 6 and 7 depicts the truth more faithfully than the other. It would be just as challenging to say that one image is a better form of documentation than the other. What is certain is that the image produced by Forensic Architecture references a form of media for which the threshold of detectability has been magnified from a single image depicting a person's death to several hundred. We must also keep in mind that not being present for neither Cook's nor Elçi's deaths, we are only able to act upon and speak about these events by way of the media representing them. This warrants a moment of pause precisely because, during the eighteenth century, an image like Webber's was considered by many to be an accurate image in the way that Forensic Architecture's is today. It may be that our collective fascination with images as communicative tools and as documentary recording devices has not changed very much in the preceding two-and-a-half centuries. What has changed, and dramatically so, is the threshold of detectability and the culturally assigned limits we set as the norm for truthfulness, accuracy, and fidelity.

Weizman addresses the influence of media upon thresholds of detectability when he acknowledges a shift from witness-oriented testimony to object- or "thing-" oriented testimony, during the second half of the twentieth century (Keenan and Weizman 2012, 11-13). We see this shift in action when Forensic Architecture mutes the eyewitness' account in favor of the video-camera-as-object's account.⁷ In "The Killing of Tahir Elçi" investigation, the video camera is framed as distinct and autonomous from its holder: emphasis is not placed on who holds the video camera (the eyewitness) but on what information (audio-visual data) is contained on the camera's memory card (the object). The reason for this, we might surmise, is because we are encouraged, in the present, to see in Webber's image all possible personal biases. This renders the image's usefulness in answering questions surrounding the circumstances that resulted in the 1779 death of Captain Cook in Hawaii extremely unlikely. Alternatively, we do not have the same reservations when Forensic Architecture poses versions of these same questions to four video cameras. And why? Put simply, it is because the video cameras magnify the threshold of detectability to a degree we find satisfactory.

Thus, we are left with two distinct thresholds of detectability, albeit constructed by similar means. In the case of the death of Captain James Cook, a single painting believed to be authored by Webber between

1781-3 (figure 8) serves as the surviving visual evidence of the event that led to the production of the copperplate etching reproduced in figure 6. Like the makers of Forensic Architecture's 3D model who could not visit the site in which Tahir Elçi was killed—it is noted in the video investigation that the area of Diyarbakir in which Elçi was killed was razed some weeks after the murder—Francesco Bartolozzi and William Byrne were in a different global hemisphere at the time of Cook's death. Bartolozzi and Byrne's capacity to act as translators—the former working with the figures, the latter with the landscape—rendering Webber's painting as an etching, and thus an image capable of mass reproducibility, is similar to that of the Forensic Architecture model makers, who take disparate and peripheral forms of evidence—publicly available satellite imagery, building elevation drawings, leaked police documents including video and photographic images—and construct a single 3D model capable of being located in a web-based and distributable video. Although achieved according to historically distant and distinct culturally-determined standards, both the print and video may be understood as endeavoring to collate as many evidentiary forms as necessary, in order to yield a reproducible image capable of speaking for the event depicted and carrying with it the highest possible threshold of detectability.

3. 'A' IS FOR ANALOGY: MENGELE'S SKULL AS A THEORY OF METHOD⁸

Coauthored by Eyal Weizman and Thomas Keenan in 2012, *Mengele's Skull: The Advent of a Forensic Aesthetics* was published just two years after Forensic Architecture was founded. Elucidating the shift from witness to object-based testimony, Keenan and Weizman's book deals with numerous images from forensic scientist Richard Helmer's "face-skull superimposition demonstration" carried out at the Medico-Legal Institute Labs in São Paulo, Brazil in June 1985 (Keenan and Weizman 2012, 38). As Keenan



Figure 8: John Webber's oil painting [Death of Cook], c. 1781-83. (State Library of New South Wales)

and Weizman situate them, the images depicting Helmer's forensic analysis served to convince a public audience that the skull of a recently exhumed body did, in fact, belong to Nazi war criminal Josef Mengele. We can identify in these images two notable qualities that consistently feature in Forensic Architecture's investigational work of the last decade. Presenting photographs of a living Mengele alongside those of a faceless skull, Helmer's studies yielded (1) side-by-side sliding comparisons in addition to (2) comparisons made on the basis of transparency (i.e. fading out one image to be supplanted by another). Relying on visual as opposed to verbal rhetoric, Helmer's demonstrations effectively convinced viewers that the superimposition of two different images—scientific analysis performed upon a recently exhumed skull on the one hand and a photograph of a living person on the other—could be read as speaking to one and the same event: in this case, a person identifiable as Nazi war criminal Josef Mengele.

Similar phenomena of simultaneity and transparency may be observed in the stills from Forensic Architecture's "Ali Enterprises Factory Fire" investigation reproduced in figures 1 and 2.⁹ During the four seconds that span the temporal gap between these still-images, the photograph visible at the center of figure 1 steadily gives way to the 3D model visible in figure 2. This visual rhetoric is comparable to that used in Richard Helmer's images from thirty years earlier. And, at a conceptual level, figures 1 and 2 depict a key characteristic of nearly every one of Forensic Architecture's investigations: the claim of fidelity that exists between a 3D model and firsthand documentation of a specified event.

We must not fail to acknowledge that it is during these moments in the video investigations that Forensic Architecture's arguments are at their most vulnerable. If a viewer is not convinced that the 3D model corresponds to available primary-source material and they cannot subscribe to the model's ability to speak for the event targeted by the investigation, then Forensic Architecture's inquiry cannot proceed. This is because, from these moments onward, the 3D model stands in for the site in which the referenced event took place. Given that Forensic Architecture's investigations usually target geopolitical sites which no longer exist or are otherwise difficult to access, the fidelity of the 3D model is of singular importance. In the same way that a public audience had to be convinced that an anonymous skull formerly carried the face of a man named Josef Mengele, Forensic Architecture must convince their viewers that a digital model corresponds to a burned-down factory in Pakistan, or the razed sector of a city in Turkey.

We can observe the implications of this polemic in "The Killing of Tahir Elçi" investigation. Once the investigation turns exclusively to 3D model space, we do not question the veracity of the locations of any of the actors or the architectural layout they inhabit (figures 9-10). Instead, we are accounting for bullets discharged and the orientation of weapons and their carriers as the event plays out. We do not worry about the fidelity of the model or its resolution. As Forensic Architecture likely intends, we worry about which scenario seems most likely to have occurred in the space and time for which these models speak. In figures 9 and 10 we see very clearly that the scenario is being played out in a digital model but, in our mind's eye, we apply this scenario to the historical space and time for which the model convincingly speaks. As we did earlier with figures 1 and 2, comparing now figures 7 and 10 demonstrates how Forensic Architecture primes us to associate their 3D model with the space referenced with primary-source evidence. Hereafter, anything Forensic Architecture acts out or simulates in the 3D model, a viewer sees as being acted out in the spatiotemporal condition in which the event actually took place. It is for this reason that a Forensic Architecture investigation can be frighteningly convincing: the counter-scenario they enact leads us to effectively believe that we have witnessed—firsthand and in person—the true event.

CONCLUSION

Zeno's Dichotomy Paradox and the Ethics of Historiography

Zeno's dichotomy paradox states that before a person traverses the distance between two points that person must first traverse half the overall distance. And after traversing half the overall distance that person must traverse one half of the remaining distance. And after traversing that distance, another half-distance must be traversed *ad infinitum*. The paradox concludes by stating that in order to traverse the distance between two points one must first complete an infinite number of successively smaller tasks.

The density of available visual content describing contemporary events relates our inquiry into Forensic Architecture's investigatory work of recent years to Zeno's paradox. While the unaccounted for space between an event and its imaging is getting smaller, a gap is nevertheless present. It is not difficult to debate the veracity of the copperplate etching describing the death of James Cook because it was produced four years after the event and at a navigable distance of more than 25,000 miles. And, even if we identify Webber's painting as a more credible image—after all it was produced *by* and not *after* Webber—it is still only

thought to have been painted as early as 1781, a full two years after Cook's death. Jump forward to the killing of Tahir Elçi and we find 940 still-images describing his death; images, it may be argued, that were produced simultaneously to the event and at a rate of one image every 0.03 seconds. And because the cinematic sequencing of these images renders individual frames imperceptible to the human eye—we can only discern the difference between individual frames up to a rate of about 15 frames per second—we are left to believe that they are seamless, and contrary to their existence, completely fluid. This is not the case, however, and the videos gathered by Forensic Architecture do in fact contain blind spots. Consider, for example, that the cameras from which the primary-source videos were produced captured at a rate of 30 frames per second instead of 25. Given the parameters of Forensic Architecture's investigation, this would add 180 images to the investigation. Add another camera (from CCTV, a bystander's cell phone or a police bodycam) and, capturing 25 frames per second, another 235 images enter into Forensic Architecture's investigation. In addition, if the four cameras present at the time of Elçi's death captured at a rate of 60 frames per second, 1,260 images would be added to the investigation, effectively doubling the relevant media to parse through.



Figure 9: Still from 00:08:37 of Forensic Architecture's "Killing of Tahir Elçi" investigation. This image depicts the events surrounding the killing of Tahir Elçi only through 3D model space. (This view is perpendicular to that depicted in figure 10). (Forensic Architecture, "The Killing of Tahir Elçi" 2019)

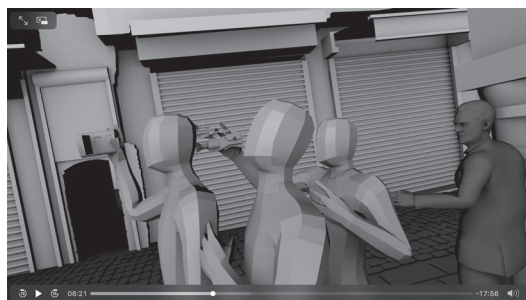


Figure 10: Still from 00:08:21 of Forensic Architecture's "Killing of Tahir Elçi" investigation. (Forensic Architecture, "The Killing of Tahir Elçi" 2019)

The analogy to Zeno's dichotomy paradox serves to remind us that we are dealing with an ever-present gap between an event and its reproduction. The gap of time and space may be shrinking, and at exponential rates toward imperceptibly small distances of time and space, but for now it is still present, and we must acknowledge it.

So, when the discussion shifts from the witness to the "thing" (as we see at the start of Keenan and Weizman's *Mengele's Skull*), it is not so much that we stop trusting the witness as much as we reorient who functions as a witness and in what capacity. In the mid-1980s Keenan and Weizman identify a shift away from the witness as someone able to speak about an event towards someone tangential to the investigatory scene, like a scientist, tasked with speaking for, about and through objects that act as witness to the event in question. In terms of images like the ones featured in this paper, a witness no longer produces images in the way that Webber did with Cook's death, but instead interrogates the evidence which witnessed or "sensed" the event, much like Forensic Architecture does with video-camera footage. With this shift comes the immense responsibility of speaking for these object-oriented witnesses.

We might now recall certain pre-Hegelian models of art and architecture historiography. In *Threads and Traces*, Carlo Ginzburg (2012) claims that "modern historical writing came into being from the convergence...between two different intellectual traditions: Voltaire's type of *histoire philosophique* and antiquarian research" (13). The antiquarian research that Ginzburg describes was conducted by a person who, contrary to the established practices of the seventeenth-century historian, "used nonliterary evidence to reconstruct facts connected to religion, to political or administrative institutions, to the economy—spheres not touched upon by historians tendentiously oriented toward political and military history. . ." (12). Perhaps most relevant to the questions outlined in this paper, Ginzburg says that the shift toward "modern historical writing" came about precisely when, "in the second half of the seventeenth century...one [began] to analyze systematically the differences between primary and secondary sources" (12). In Ginzburg's account, the debates that occupied historians of the fifteenth through seventeenth centuries centered around which objects should fall under the historian's gaze, what he or she did to manipulate these objects, and the historical narratives that resulted. In briefly recalling these debates, I am compelled to bring to the foreground those models of historiography which were *not* codified: those models predating the systematic parsing of primary and secondary sources. These are

models for which, we might conclude, synthesis among speaker, content and reference was not only seamless, but a desired condition offering historical truths by way of *energeia*: what Ginzburg summarizes as a series of "procedures" with which ancient historians attempted to communicate that "effect of reality" through oratorical strategies, such as "activity," "clarity," and "vividness" in the Homeric tradition, and which ultimately resulted in a "guarantee of truth" (8-9).

Weizman speaks to this notion of the continuity between speaker, content and reference when he writes about Quintilian's concept of *prosopopoeia* in a text from 2010, predating the publication of *Mengele's Skull*, and coinciding with the earliest investigation published on Forensic Architecture's website. Weizman writes that "because the thing speaks through, or is 'ventriloquized' by, its translator, the object and its translator constitute a necessary and interdependent rhetorical unit" (Weizman 2010, 11). Undoubtedly this "interdependent rhetorical unit" is characteristic of the relationship we have observed among primary and secondary sources in

Forensic Architecture's most recent investigational work.

In *Mengele's Skull*, Keenan and Weizman (2012) tell us that, "The shift in focus from the living to the dead, from the witness to the bones or the missing person, from memory and trauma to a forensic aesthetics, also erodes the otherwise clear distinction between subjects and things" (70). This is precisely what this paper hopes to show: in the same way that Ginzburg wrote the territory out of which modern historiography emerged was not uncontested, Forensic Architecture brings to light the methods and the forming of this contested territory in the present. This is a territory for which subjects and things, speakers and spoken for need not be so clearly differentiated. The forms of historiography, in which we treat as an asset the erosion between subjects and things, are those that might render history more relevant in an age when speaking about or of some *thing* is increasingly difficult when that thing demands to be spoken for. In the present, Forensic Architecture is certainly one of these speakers, speaking for the objects falling under their investigative gaze.

ENDNOTES

1 As of November 2019, Forensic Architecture groups the work featured on their website under one of two headers: "investigations" and "programme." The latter category is broken down into several subcategories: "exhibitions," "events," "news" and "publications." The projects included in this paper may be found under the "investigations" header on the Forensic Architecture website.

2 Forensic Architecture's investigations sometimes simultaneously exist in different media including print media, web-based internet videos and museums. In this paper, my references to Forensic Architecture's investigations are restricted to those versions of an investigation as they appear on Forensic Architecture's website.

3 In this and many other investigations undertaken by Forensic Architecture, the space in which the crime being investigated took place no longer exists. It is for this reason that the 3D model may be said to speak *for* these spaces and not *about* or *to* them. It is also for this reason that the 3D model is such an important component of Forensic Architecture's investigations: the sites in which the scrutinized event initially occurred can no longer be visited.

4 It is often the case that 3D models and the software in which they are made—particularly in design-oriented disciplines—are used as projective tools, created before, or in anticipation of the event or object for which they speak. The fact that Forensic Architecture creates 3D models after the event for which the model is intended to speak is somewhat unique and relates their investigational work to other historically-oriented projects.

5 "Split second" is a term I have borrowed from the title of Weizman's postscript in *Forensic Architecture* (2017): "The Slow Violence of the 'Split Second'."

6 Of the events depicted in figures 3, 4 and 5 "The Ali Enterprises Factory Fire" is framed as an event lasting thirty-eight minutes, "The Murder of Halit Yozgat" lasting nine minutes and 26 seconds, and "The Killing of Tahir Elçi" lasting nine seconds and ten camera frames.

7 This especially is the case today with body-cam footage, which is taken as "evidence," often calling into question police officers' testimony.

8 In *Heuristics: The Logic of Invention* Gregory Ulmer outlines the acronym CATTt as a tool not only helpful in analyzing but inventing method. Ulmer first demonstrates CATTt on André Breton's *Surrealist Manifesto*: "A comparison of Breton's manifesto with the various classics of method [namely Plato's *Phaedrus*] reveal that they tend to include a common set of elements, which are representable for mnemonic reference by the acronym CATTt. The CATTt includes the following operations: C = Contrast (opposition, inversion, differentiation), A = Analogy (figuration, displacement), T = Theory (repetition, literalization), T = Target (application, purpose), t = Tale (secondary elaboration, representability)," (Ulmer 1994, 8). It follows that I read *Mengele's Skull* as the Analogy in Forensic Architecture's CATTt.

9. Although I have only selected two investigations dating from 2018-2019, these examples are not uncharacteristic of Forensic Architecture's earlier work. As of May 2019, only one of the forty-two investigations featured on Forensic Architecture's website predates the 2012 publication of *Mengele's Skull*.

REFERENCES

- Forensic Architecture. 2018. "The Ali Enterprises Factory Fire." Published January 30, 2018. Video, 17:54. <https://forensic-architecture.org/investigation/the-ali-enterprises-factoryfire>.
- Forensic Architecture. 2019. "The Killing of Tahir Elçi." Published February 8, 2019. Video, 26:18. <https://forensicarchitecture.org/investigation/thekilling-of-tahirelci#toggle-id-1>.
- Forensic Architecture. 2019. "CGI Crime Scene Reconstruction Opens New Leads in Kurdish Activist Killing." Open Democracy. Last modified February 8, 2019. <https://www.opendemocracy.net/en/cgi-crime-scene-reconstruction-opens-new-leads-in-tahir-elci-killing/>.
- Forensic Architecture. 2019. "The Murder of Halit Yozgat." Published June 8, 2017. Video. 28:55. <https://forensicarchitecture.org/investigation/the-murder-of-halit-yozgat>.
- Ginzburg, Carlo. 2012. *Threads and Traces: True, False, Fictive*. Berkeley and Los Angeles: University of California Press.
- Keenan, Thomas and Eyal Weizman. 2012. *Mengele's Skull: The Advent of a Forensic Aesthetics*. Berlin: Sternberg Press.
- National Portrait Gallery of Australia. n.d. "The Death of Captain Cook, 1784." Accessed November 11, 2019. <https://www.portrait.gov.au/portraits/2007.28/the-death-of-captain-cook/>.
- Ulmer, Gregory. 1994. *Heuretics: The Logic of Invention*. Baltimore and London: The Johns Hopkins University Press.
- Weizman, Eyal. 2010. "Forensic Architecture: Only the Criminal Can Solve the Crime." *Radical Philosophy* 164, (Nov/Dec): 9-24.
- Weizman, Eyal. 2017. *Forensic Architecture: Violence at the Threshold of Detectability*. New York: Zone Books.

A STUDY ON COMMUNITY PERCEPTION TO IMPROVE THE URBAN GREEN SPACE DENSITY: A Case Study of Can Tho City, Vietnam

Phuong Phi Pham, Se-Guy Oh
Chonnam National University

Abstract: The study aims to examine the green density in Can Tho City, Vietnam, where urbanization has been rapidly growing and urban green space has gradually disappeared, because built-up land has been increasing rapidly over the last 20 years. First, this study conducted a survey and interviewed the local people to discover residents' perceptions about the current quality of urban green space and explore the existing problems. The survey focused on green space density, current housing types, and the quality of housing to suggest a vertical resettlement concept for improvement of green space. The results of the survey questionnaire demonstrate a lack of green space in the center of the city, and local people entirely concur with the need for relocation into high rise buildings, in order to cede land to green spaces. Thus, the study chooses to research an area, where the survey results reveal that the current housing conditions and quality of life of the inhabitants is low and chaotic, and therefore, the solution of the vertical resettlement is considered a suitable solution in this case. The solution can thus enhance the living conditions of the inhabitants, allowing them to optimize land use planning in this study area.

Keywords: Urban green space, questionnaire survey, residents' perception, improving green space, vertical resettlement concept

INTRODUCTION

Can Tho is known as the largest city in Vietnam's Mekong Delta. According to the government's development plan, Can Tho is expected to become one of the regional hubs, connecting critical economic centers of the South East Asian region (Ho Chi Minh, Phnom Penh, and Bangkok) in the future. This is the reason why strong urbanization in Can Tho city has been occurring for the past twenty years. Rapid population growth in the center of Can Tho has caused problems not only from a social, but also from an environmental point of view, such as environmental pollution, lack of public space, lack of housing, urban heat islands, and flooding. Ninh Kieu is one of the core districts in Can Tho, placed at the intersection of the Hau and Can Tho rivers that bring advantages in both agriculture productions and urban development, but also challenges, for example the risk of flood and a lack of housing in Nink Kieu. According to the World Bank (ISET), increasing green surface in urban areas is one of the more important objectives, in order to reduce the flood risk and develop the urban landscape.

Urban green space is planned following governmental standards and its quality is measured by expert assessment, but there are always gaps between urban planning projects and the reality as it unfolds in Vietnam. So, the current green areas are insufficient to meet the demand of citizens in the main cities of Vietnam. One of the drawbacks of governmental standards for determining green space quality is the fact that the satisfaction and attitude of the local

population is not taken into account. Hence, a survey of the citizen perceptions is an important tool for providing the information to set the future direction of urban green spaces. Local communities clearly understand the existing issues in their living areas through the activity of daily life. In fact, other studies have shown that local people's perception is shaped by knowledge about the goals and characteristics for protected areas as they relate to socioeconomic factors. In this study, the perception of the current issues of green space and the local population's attitudes toward urban green space are examined in 110 households in the central Ninh Kieu district.

Approximately 90% of respondents perceive a lack of green space in their living area and approximately 80% of respondents hold positive attitudes toward the replacement of slum area in urban and vertical resettlement development. In fact, the success of the vertical resettlement to improve the slum area in Mumbai City-India is a real case study that the other cities of Asia may refer to. This model resolves the twin challenges of lack of housing and the need for land use in an urban setting. However, each country has different social, economic, and cultural factors, so the application of the vertical resettlement in Mumbai city to Vietnam should be carefully considered, with the goal of community satisfaction.

The study is designed to determine the existing green space by the collection of local people's perception. For this purpose, a survey questionnaire

A Study on Community Perception to Improve the Urban Green Space Density



Figure 1: (a) Theory of Le Corbusier for Contemporary city. Source; (b) The Architectural model of the 50-storeys public housing development at Duxton Plain; (c) Two areas in Mumbai are a mixture of urban sprawls and vertical urban.

and face to face interview were conducted for 111 households in Ninh Kieu district, Can Tho City, Vietnam. It is expected that the results will provide the data to determine planning parameters for urban planners and architects, particularly focused on increasing green space in urban areas. In the same way, the study shows that the suggestion of applying the vertical resettlement model in slum areas will be supported by up to 80% the local community.

1. LITERATURE REVIEW

1.1. REVIEW OF VERTICAL RESETTLEMENT CASES

The first vertical development concept was designed in 1922 by Le Corbusier. He proposed a plan where three million inhabitants would be housed in a specially designed "contemporary city". The concept was understood as moving the living space to a vertical direction thus avoiding residential sprawl in urban areas that is equivalent to the unplanned urban growth these days. According to Le Corbusier, overpopulation is one of the serious problems of modern cities, so he proposed housing blocks- and skyscrapers- encircled by gardens, in order to accommodate high density in the city center, which corresponded to the redevelopment of a large area of Paris. These skyscrapers proposed the high density, in order to leave at least 85% of the ground free for green space (figure 1a).

The adaptability of the concept of a vertical city was also studied as a solution for land scarcity in Singapore where the area is approximately 660km², the population is 5.5 million and Singapore needs to cater to about 80,000 housing units. So, the Singapore government provided accommodation for citizens by creating a fifty-storey public housing development at Duxton Plain in 2002. This project is complemented with numerous other types of land use within the same structure, especially focused on providing quality housing with good natural lighting, ventilation, orientation, and views. With the vertical city concept,

this building type received 50.8% of the respondents in favor of the fifty-story public housing development at Duxton Plain. This means that the perception of inhabitants favored this concept (figure 1b).

According to the study by Grace Wong, this shows that, although some vertical city proposals come across some opposition, they have become a common trend in Asian countries. Vertical development is also examined as a potential application to solve the issue of slums in chaotic cities. For example, Mumbai (Bombay) is India's main industrial and commercial center with a total area of 5027sq km and a population of 27.5 million at the last formal census in 1991. In Mumbai, the huge population pressures on the limited land area led to the lack of housing units in the city. Therefore, many apartment blocks were built to supply housing for citizens; inhabitants of the slum areas were convinced to move into high rise buildings constructed on the original area, in order to leave land for open space. This model was considered an important solution to replicate in cities with similar situations (figure 1c).

1.2. VERTICAL RESETTLEMENT ADAPTS TO THE VIETNAMESE URBAN CONTEXT

1.2.1. THE SUCCESS OF THE HIGH-RISE BUILDING PROJECT

Urbanization in Vietnam has advanced faster than in other regional countries. A number of areas are recognized as urban areas of accelerated development. In Vietnam, the percentage of population living in urban regions rose from 19% to 26% in the period 2000-2010. Thus, the large cities in Vietnam such as Ho Chi Minh, Ha Noi, Da Nang, and Can Tho are facing a lack of housing, built land, and environmental pollution. In Ho Chi Minh City, urban upgrading projects were supported by many developed countries to solve the environmental, housing, and social challenges. One of them is the THLG project supported by Belgium, which was considered a success when completed in 2006.



Figure 2: (a) Tan Hoa Lo Gom canal in Ho Chi Minh City (before the project started); (b) The Architectural model of the three-story apartment buildings (after the project finished)

To provide residence for poor migrants along canals, the situated apartment comprised three-story blocks designed in consultation with the future users, so as to leave open public land for playgrounds, green areas, and motorcycle parking. In particular, residents could live close to the street level, which is quite handy for their economic activities (figure 2). This project was considered a success in providing the accommodation and, public space for 42% of the households with the lowest social status, while simultaneously addressing the canal's heavily polluted water.

In the context of Vietnam, large cities such as Ho Chi Minh, Ha Noi, Da Nang, Can Tho have been pressured by the huge migration in recent years. Lack of housing for the households with the lowest status, especially the residents along canals in city is a complex problem for the government. The success of the Tan Hoa Lo Gom project in Ho Chi Minh city, it shows that the vertical city concept can be applied to the current issues in Vietnam, and to Can Tho City in particular. Although many Vietnamese urban planners and architects advocate for the vertical city concept as a solution to the expansion of the cities in Vietnam, their studies do not note the needs, perceptions, and reactions of the residents thus leading to conflict between government and residents. Herein, a study has been executed to access the resident's acceptance of living in a high-rise apartment building. This is the first step for obtaining the residents' perception in Nink Kieu district, on whether or not they are willing to live in high-rise housing.

1.2.2. CHANGE IN HOUSING TYPOLOGY IN VIETNAM

There is a difference in living style between the rural regions and urban areas in Vietnam. In the rural region, people live in rural homes - this housing type has the only one level, but it has a large area and is in harmony with the surrounding environment. In contrast, because of the rapid urbanization and population growth in the city, housing construction is chaotic and has led to diverse housing styles. There are five housing typologies in large cities: the rental house, slum house, old apartment, modern apartment, and tube house. (table 1). High rise buildings especially have gradually evolved day by day to adapt to the Vietnamese living styles. First, these types' floor area is usually small, around thirty square meters, with a sleeping area, restroom, and kitchen. It is tiny and not enough space for the multi-generation family in Vietnam. So, recent construction has changed in the spatial configuration and the floor area is now large (over fifty square meters), with two-bedrooms and many other functions. As a result, Vietnamese people have gradually moved to high-rise buildings in large cities.

In addition, a survey of the existing high-rise apartments in Can Tho City was performed, and residents stated that most built apartments lack common space, such as parks, motorbike parking, etc. Another finding was that the lack of space for small businesses on the street level, because of the narrow pavement. This should be considered an important request of high-rise dwellers-these buildings should add



					
Rural Region	City Fringe			Central City	

Table 1: The difference in housing typology between rural regions and cities.

A Study on Community Perception to Improve the Urban Green Space Density

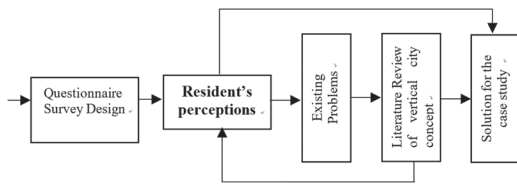


Figure 3: Summary of the procedure of research. (Author 2019)

common space and have more green spaces, like a rural setting, or spaces for businesses. This will reduce the drastic change in the style of living of the Vietnamese. With this solution in mind, the apartment typology will attract the attention of the Vietnamese.

2. METHOD

2.1. STUDY DESIGN

The study data used was derived from the case study in Ninh Kieu district. This study follows a stepwise procedure to select the solution for improvement of urban green space density that had been evaluated by the residents' survey. First, the study designed the questionnaires based on the research purpose and with reference to the related documents. Second, the study conducted a survey questionnaire and interview in February 2018 to collect information on two elements: existing green space and vertical development concepts (figure 3).

2.2. STUDY AREA

The study selected an area of 5x5 square kilometers at the center of Ninh Kieu district, Can Tho City. One of the notable things in this area is the permanent complexity of the residential area, commercial area, and tourist area. The residential area is characterized by tube houses and two-story block houses in the French style, while the other areas possess structures such as banks, hotels, restaurants, civic and religious buildings. Toward

the middle of each plot, some of the existing housing in the case study, revealed slum-like, poor conditions.

In order to propose a specific solution, block one and two in the study area are considered as sample research for green space improvement (see figure 4c). The study expects that the results will be a clear concept to be applied not only to the Ninh Kieu district, but also to the other cities in the Mekong Delta.

2.3. DATA COLLECTION TECHNIQUES

To explore the local perceptions of the twin issue of the current green space and the relocation to a high rise, the study collected the data in February 2018 by using survey, in-depth interview, and field observation. These methods play an important role in directly collecting and synthesizing local perceptions from different households.

Questionnaires

The survey was divided into two sections. Section 1 comprised evaluating the quality of life and confirming the existing problems in the study area. The measurement of urban green space density was determined through a series of focus questions with inhabitants living in the study area. Section 2 comprised a group of questions that relate to the solution for improving the urban green space.

Data were collected by means of paper-mailed questionnaires that were randomly distributed to the inhabitants in 2018. Five questions evaluate the perceived quality of life with suggested multiple-choice answers and room for respondents to express their own opinions. While from question number six to ten comprises qualitative questions which the respondent must choose according to their perception (table 2).

The diverse information obtained from the local people will help urban planners embrace all sides of the issues currently at play in the study area, in order to find the most suitable solution to improve the green space density and the most appropriate use of urban land, all with the goal of achieving a higher quality of life.

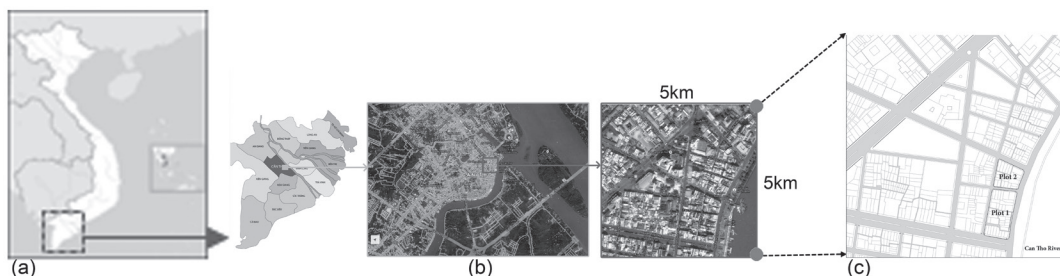


Figure 4: Study area location: (a) Mekong Delta Location; (b) Can Tho City Location; (c) The case study with two plots as example for vertical city concept. (Author 2019)

#	Question	Related result
Evaluation Question about the existing problems in the study area		
Q1	To evaluate your satisfaction with the quality of life in the study area by green space.	Level of satisfaction (There is a relationship between the qualitative feature of green space and residents' self-reporting)
Q2	To increase the quality of life in the area, which of the following space is most necessary?	Perception of green space
Q3	According to your opinion what disadvantages are occurring in the area where you are living in?	Perceived the negative aspects of life that is the cause of disappeared green space
Q4	How many green spaces are there within a 20 minutes walk from your house?	The standard distance to the nearest green space. With 20 minutes' walk, the distance proposed 700 meter from house to green space (according to an accessible green space standard of Bristol City Council in 2008).
Q5	If your answer in number four question is having green space. May you describe the green space?	Observation
Evaluation Question about the vertical city concept to improve the urban green space		
Q6	According to the below describe: What kind of urban green space do you want? 1. Public space is like square 2. Public space has many functions such as green space, playground, motorcycle parking.	Perceived the kind of green space
Q7	To increase the quality of life in the area, the government should be renovated in the area. What solution would you like to agree with?	Perceived living habit
Q8	Give your opinion about this solution. Resettlement solution with residential space is organized follow on the vertical like the apartment to create the green space on ground floor.	Perceived the level education and nature
Q9	Give your opinion about Apartment buildings from 2 to 5 floor have green space and public space	Perceived living habit

Table 2: Question used for the survey

In depth-interview

In total, 111 out of 200 distributed questionnaires were returned. All 111 samples contained complete data available for analysis. All participants in the survey were long-term residents of the study area, and most of them had been in this area for over eight years.

Out of the respondents, the largest participation age cohort in the survey were between 45 to 60 (53.3%) and smallest was aged 18 to 24 (6%). The remaining balance of the participants were aged 28 to 36 (40.7%). The highest proportion operated a small business (occupying 34.1%). Second, the degree of education achieved by respondents (college graduate or more) was 20%; this is followed by students, and workers. Most of the respondents have a stable monthly income to support their family.

The mentioned survey samples are confirmed to be selections that are random, and that are universally representative of the study area, thus exposing the various dimensions of the experience of the local populace.

2.4. DATA ANALYSIS

The collected data was simply analyzed by statistical analyses which was performed by using SPSS software version 23. All inhabitants' opinions in the study area are described by using descriptive statistics. The descriptive statistics provides simple summaries about local perceptions via table 2. The study investigates a number of cases that fall into various categories, so the frequency option is carried out to obtain the number of people within each category in the dataset.

The study not only observes and analyzes the green space, buildings and local people, but it also listens to what participants have to say and records the length of time the participant has lived in the research area. The data was gathered in the form of handwritten notetaking on the map and photography; these revealed multiple problems in the slum area. In fact, the local populace is living in conditions of environmental pollution, flooding, lack of open space, and poor housing quality. These problems were assessed through observation.

3. RESULT

3.1. RESULT OF THE QUESTIONNAIRE SURVEY

During the interview, local people have shown honest, sincere appreciation and deep understanding of their living area. The results show that they are facing serious challenges of lacking green space and housing degradation. Also, they seem worried about the flooding that happens often. In tables 3, 4, the analysis shows the percentage of the most selected answers for each question. Then, the most selected answer will be considered as the remarkable survey result to evaluate the green space status in the study area.

The study demonstrates local perceptions about moving to high-rise housing, in order to leave urban land for green space, by questionnaire survey. The results are summarized in table 4. In this section, the study notes

Evaluation Question about the existing problems (green space and the quality of living) in the study area	% per total participants
Non- satisfaction with the current green space	76.6
Agree with improvement the urban green space	53.2
Densely populated informal settlements in the study area have caused environmental pollution, and chaotic area	49.5

Table 3: Level satisfaction of local people about urban green space.

Resident's opinion about vertical city concept	% per total participants
Agreement living in high-rise housing.	19.7
Agreement living in high-rise housing with the stabilization policy.	73.1
High rise apartment building is complemented with numerous functions, such as green space, playground, and motorcycle parking.	92.8

Table 4: Resident's opinion about vertical city concept

Job Variable	Agreement		Disagreement	Other
	Agreement & Stabilization Policy	Agreement without Stabilization Policy		
Officer, Doctor, Law, etc.	20			
Workers, staff	19	19.7		1.8
Businessmen	34.1		5.4	
Total	92.8	5.4	1.8	

Table 5: Job Factors affecting residents' perception about the vertical city concept

the level of education of respondents, where 20% of participants graduated from college and higher. Most agree with this solution. Also, 38.7% of the workers, office workers and students approve of the proposal. Businessmen concur with this solution, but they require that the government have the policy in place to ensure the work, and 5.4% completely disagree with this concept (table 5).

There are a number of issues surrounding the opinions of local people regarding vertical residential developments, especially small businessmen who have used the ground floor for supporting their living. The businessmen worry that moving into high rise housing they lose their business space. Therefore, the need for implementation of vertical development in parallel with an effective social policy, which ensures all people in the area may support their living.

3.2. RESULT OF THE HOUSE'S QUALITY SURVEY

Housing typology in Ninh Kieu district is various. The tube houses typology with modern architecture along the main street have been not only functional living spaces, but also lucrative for businesses, which occupy the largest percentage, as opposed to the middle of the block, where the slum-like makeshift houses are of poor quality (table 6: houses are marked in yellow, and figure 5). A large population living in slums creates multiple problems for the city, such as environmental pollution, lack of public space, lack of housing, etc.

3.3. SUGGESTED SOLUTION

From the results of observation, the study carefully surveyed two residential areas as mentioned above to illustrate the vertical concept. The purpose was to show that numerous functions such as green space, playgrounds, and motorcycle parking could coexist in the area, as compared to the current flat city, in which inhabitants do not enjoy communal green spaces. In the selected two plots, there are residential areas, ground-floor commercial spaces, offices, and institutional land use. Each of these uses have a different character and streetscape requirement. All of the households should be resettled into high rise housing, in order to leave the central zone for green space. Providing green space will transform the concrete surface and increase the capacity for flood resistance in the future (figure 6).

CONCLUSION

This study outlines an approach by the questionnaire survey to measure inhabitant's opinion of urban green space. Two main findings were presented in this research. First, a set of nine questions used to survey the inhabitant's opinion. The results show that the

Housing Location is classified by colour









			
			
2-storey block houses in French style	2-3 storey block houses	Tube Houses	Makeshift houses

Table 6: The quality of current Housing in the study area. (Author 2019)



Figure 5: Survey of existing housing in the study area in 2018. (Author 2019)

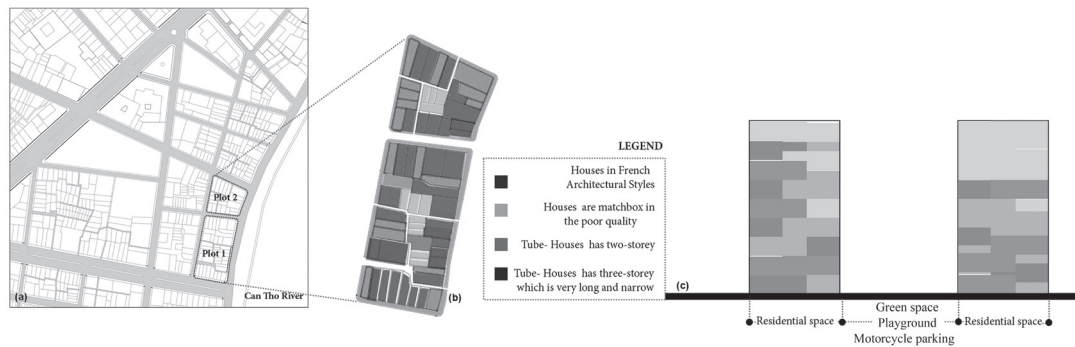


Figure 6: (a) Location of selected two plots; (b) Flat city; (c) Vertical city concept. (Author 2019)

attitude toward the urban existing issues is rightly evaluated, and the inhabitant's level of acceptability of high-rise housing is also high in spite of it is a new solution to the population in Can Tho city. It is unbelievable that over 70% of answers agree with vertical city development and the government must attach the policy to stabilize their life. Therefore, that is notable for urban planners and government when they plan to redevelop the slum in urban, the satisfaction of social issues is conducted as well as. Second, moving into the high-rise apartment to leave the urban land for green space is not only enhancing the quality of inhabitant's life, but also solve the flooding in urban due to climate change and sea-level rise.

The above analysis explores that the citizens always have a concerned attitude toward the existing issues in their area and the respondents' level of acceptability is highly dependent on whether the government has the policy to support their life. The research suggests that the local perception should be considered as a precept in the plan development of the city.

A Study on Community Perception to Improve the Urban Green Space Density

REFERENCES

- ARC Studio Architecture + Urbanism. "Singapore Skyscraper Building." Accessed 16 Jun 2010, <https://www.e-architect.com/singapore/pinnacle-duxtan>.
- Aoshima, Ippei, Kei Uchida, Atushi Ushimaru, and Masayuki Sato. 2018. "The Influence of Subjective Perceptions on the Valuation of Green Spaces in Japanese Urban Areas." *Urban Forestry & Urban Greening* 34 (August): 166-74.
- Benoit Legrand, Le Dieu Anh, Dinh Thi Le Nga, Jan Van Lint, Gerrard Baltissen, Martijn Tê Heegde. 2014. "Urban Upgrading in Ho Chi Minh City: Unexpected Social Impact of an Infrastructure Project." *BTC: Belgium*. <https://www.enabel.be/publication/urban-upgrading-ho-chi-minh-city-unexpected-social-impact-infrastructure-project>.
- Duch, R. M., A. Leyendecker, O. Lemmer, S. Esser, G. O'Hare, Dina Abbott, and Michael Barke. 1998. "A Review of Slum Housing Policies in Mumbai." *Cities* 15, no. 4 (August): 269-283. doi:10.1016/S0264-2751(98)00018-3.
- Gill, Maninder, and Ashwini Bhide. 2012. "Densification through Vertical Resettlement as a Tool for Sustainable Urban Development." Paper presented at the *Proceedings of the Sixth Urban Research and Knowledge Symposium*, Barcelona, Spain, 2012.
- Government. *How Can Urban Planning in Vietnam Be More Effective? The Case of Ho Chi Minh City* Forum Co-organized by ADETEFE and AFTS in HaNoi March 2012.
- Han, Tham Thi Ngoc, Pham Khanh Hoa, Ha Bao Khoa, and Tran Thi Van. "Understanding Satellite Image-Based Green Space Distribution for Setting up Solutions on Effective Urban Environment Management." Paper presented at the *Multidisciplinary Digital Publishing Institute Proceedings*, 2018.
- Houdrouge, Jennifer, and Kent Minturn. "An Ideal City? Contemporary City for Three Million Inhabitants (1922) by Le Corbusier." *Hubert Damisch*. December 21, 2018.
- Htun, Naing Zaw, Nobuya Mizoue, and Shigejiro Yoshida. 2012. "Determinants of Local People's Perceptions and Attitudes toward a Protected Area and Its Management: A Case Study from Popa Mountain Park, Central Myanmar." *Society & Natural Resources* 25, no. 8 (August): 743-58. <https://doi.org/10.1080/08941920.2011.620597>. <https://doi.org/10.1080/08941920.2011.620597>.
- Karakayaci, Zuhail. 2016. *The Concept of Urban Sprawl and Its Causes*. Vol. 9. doi:10.17719/jjsr.20164520658.
- Khanh, Le Dinh Van. 2017. *Resilient Cities: Case from Can Tho City, Vietnam*. ISET.
- "Long-Term Vision and Strategy for a Safe, Prosperous and Sustainable Delta." Accessed December 2013, <https://data.opendevlopmentmekong.net/dataset/e988f21c-9129-45f6-8be5-148677ba0480/resource/a520f1b1-7e84-4f65-9da6-dbb6a90d254e/download/mekongdeltaplan.pdf>.
- "Mumbai." *Unequal Scenes*. Accessed June 2018, <https://unequalscenes.com/mumbai>.
- Toan, Tran Thang. 2016. *Polycentric Urbanization in Vietnam*.
- "Urban Upgrading in Ho Chi Minh City." Accessed January 2014, https://www.academia.edu/6746097/The_Tan_Hoa_Lo_Gom_canal_sanitation_project.
- Wong, KM Grace. 2004. "Vertical Cities as a Solution for Land Scarcity: The Tallest Public Housing Development in Singapore." *Urban Design International* 9, no. 1: 17-30.

SIZA, KOOLHAAS, AND THE OTHERS: Notes on a Research into the Minutia of Architectural Experience

Ana Luísa de Sá
University of Porto

Abstract: Our research delves into the minutia of architectural experience, in a (neuro)phenomenal sense, from an architectural theory standpoint. Phenomenology of architecture and aesthetic theory offered sophisticated empirical definitions and descriptions of architectural experience for the better part of the 20th century. While the ineffable dimension of architectural experience is an inevitability, some of its previously inaccessible aspects are now coming to light, as new areas of inquiry tap into and unveil the complexity of our engagement with our surroundings—particularly through neurophenomenology and neuro-aesthetics. Thus, confirmations of previously theorized aspects and further revelations about experience and its components can now be extracted. It is our view that such confirmations and revelations are particularly interesting for architectural theory as an area of scientific inquiry. In our broader research, these are considered adjuvants in our looking for what we designate as evidence of experiential phenomena, and instrumental in further theorizing their underlying components in a way that is methodologically and hermeneutically coherent throughout. A retrospective reading of architectural theory and of architectural authorship and production is proposed in our research—a study of architectural experience in its artifacts. Through such artifacts, we seek to build an interpretive study of architects Álvaro Siza and Rem Koolhaas in their approach to architecture as a lengthy, complex, and meandering exercise, which culminates in a fully accomplished authorial work delivered to *others*, ultimately for their experience. Aspiring to a broader characterization of their authorial methods and resulting architectures, in their particular experiential qualities, we focus our attention on the specificities of two examples: *Museu de Serralves* (1991-1999) by Siza and *Casa da Música* (1999-2005) by Koolhaas/OMA. With this paper, we seek to contextualize some aspects of a larger research.

Keywords: Álvaro Siza, Rem Koolhaas, experience, intention, embodiment

INTRODUCTION

It may very well be that the definition of architecture is as elusive as the definition of (its) experience. The impossibility of an exact definition of one and the other has perhaps something to do with what Steen Eiler Rasmussen (1959) posited as “the correct idea of architecture as something indivisible”. In his *Experiencing Architecture*, the author continues, “Architecture is not produced simply by adding plans and sections to elevations. It is something else and something more. It is impossible to explain precisely what it is—its limits are by no means well-defined” (9).

In 1910, Adolf Loos (2007) had eloquently conveyed a similar idea that “a true building makes no impression as a picture, reduced to two dimensions.” Loos continued, in his particular jest, “It is my great pride that the interiors I have created are completely lacking in effect when photographed; that the people who live in them do not recognize their own apartments from photographs . . . [M]y kind of work *cannot* be represented graphically” (78, original emphasis).

Rasmussen (1959) follows with the adage: art (and assuming the author here means, *therefore*: architecture) “should not be explained; it must be experienced” (9),¹ something that can easily be said of

Loos’s *raumplan* architecture: it’s hard to describe, one has to experience it. It is precisely through the *in situ* experience of architecture that its indivisible nature becomes apparent. Paradoxically, the very means through which this realization is possible also belongs to the realm of the indivisible. Experience, like architecture, is also greater than the sum of its parts.

“[E]mbodiment as lived experience”, as formulated by Chilean neuroscientist Francisco Varela (1996, 346), is especially applicable to architecture. While inaccessible in its entirety merely through the observation of its parts, that architectural experience may be encompassed by the concept of embodiment is a notion that intrigued and informed our research from the outset, and that there is evidence of architectural experience as a process of embodiment to be found is an intriguing possibility we are exploring, as well. Thus, here, *architectural experience* is meant in the entirety of its embodied nature, in a (neuro)phenomenal sense.

“*L’espace indicible*,” as formulated by Le Corbusier (2000, 25), may not be fully translated and indeed translatable into words, nor the entirety of its processes understood. Nevertheless, while the ineffable dimension of architectural experience is an inevitability, some of

its previously inaccessible aspects are now coming to light, as new areas of inquiry tap into and unveil the complexity of our engagement with our surroundings. Thus, confirmations of previously theorized aspects and further revelations about its components can now be extracted. Once these components become apparent, is it then possible to venture into identifying evidence of architectural experience, similarly to how components of architecture may be considered evidence of a much larger phenomenon?

1. CONTEXT OF AN ARCHITECTURAL THEORY RESEARCH ABOUT EXPERIENCE

Recent technological developments, particularly paradigm-shifting for the cognitive sciences and the neurosciences—notably, the advent of fMRI—allow for unprecedented inquiries and understanding of the mechanisms of experience, unveiling progressively its myriad of components.² The lines between cognitive science and neuroscience are at times blurred of late. Here, *(the) neuroscience(s)* is used as a general term encompassing both. A distinction should firstly be established between what is here designated simply as *neuroscience of architecture* and *neuroscience for architecture*. That a distinction can be made is at times not clear or indeed acknowledged when dialogues between neuroscience and architecture are concerned, especially outside the focal point of their niche literature. If architecture is considered an object of inquiry and fertile ground for the survey of embodiment through the neurosciences, similarly to how works of art have proven to be particularly important as such, this would be referred to as *neuroscience of architecture*—a line of inquiry we are interested in. *Neuroscience for architecture*, on the other hand, would offer the possibility of establishing operative knowledge with a neuroscientific basis for the achievement of a given experiential result in architecture—a parallel, yet separate, line of inquiry, and one not explored within the scope of our research.³

In our research, we delve into minutiae of architectural experience, in a (neuro)phenomenal sense, from an architectural theory standpoint. Phenomenology of architecture and aesthetic theory are of paramount importance, as they offered sophisticated empirical definitions and descriptions of architectural experience in its complexities for the better part of the 20th century—classic works as *Survival Through Design* by Richard Neutra (1954), *Genius Loci: Towards a Phenomenology of Architecture* by Christian Norberg-Schulz (1979) and the aforementioned *Experiencing Architecture* by Rasmussen (1954) regain particular relevance here. Although phenomenology of architecture, may have

been considered as somewhat dated, a newfound interest has emerged as developments in neuroscience now open the possibility of (re)validation, through an intricate combination of philosophical theories and neuroscientific studies, and particularly through the recently founded neurophenomenology (1996) and neuroaesthetics (2002)—as neuroscience tries to find solutions for its *hard problem*,⁴ and points exactly in the opposite direction of Cartesian Dualism, in which mental phenomena had been theorized as non-physical. Hence, a number of architecture theorists have directed their attention to what potential may emerge from architecture's encounter with these relatively recent areas of inquiry. *Mind in Architecture* (Robinson and Pallasmaa 2015) and *Architecture and Empathy* (Pallasmaa et al. 2015) are recent publications composed of essays penned by both architects and neuroscientists, proposing exciting discussions on how this potential is already coming, and may further come, to fruition.

Architecture and Embodiment by Harry Francis Mallgrave (2013), is a particularly relevant achievement in exploring such potential. An intricate fabric is woven with phenomenology of architecture, aesthetic theory, and neuroscientific findings, to demonstrate the possibility of expanded explanations of experiential phenomena particular to architecture. Furthermore, Mallgrave (2013), architect, historian, and theorist, offers balanced chapters, summoning neuroscientific discoveries in the interpretation of phenomena particular to architectural experience, while arguing the significance of the moment at hand, stating:

The design fields . . . have had more than their share of tangents over the past half century, and designers are rightfully grown weary or distrustful of theory and its extracurricular “-isms.” But something new is distinctly coming into view. We are beginning to understand not only the biological complexity of our embodied natures but also our profound implication with the physical environment at large. All of this should give us pause for reflection. (16)

Mallgrave (2013, 11) states many of aesthetic theory's hypotheses “were remarkably close to what we are learning today” even if “speculative in nature and based on limited psychological knowledge,” indeed, a conclusion the founder of neurophenomenology, Francisco Varela (1996), had previously proposed, and Semir Zeki, founder of neuroaesthetics, recognized as a corollary of his studies (Semir Zeki, *Neuroscientist* 2017). It is precisely in the vis-à-vis between phenomenology of architecture and aesthetic theory with the neurosciences that such conclusions can be reached. This opens the possibility of recognizing when phenomenology of architecture and architectural theory *tout court* have correctly characterized aspects of experience, while additionally making it possible

to identify how architects have similarly intuited this and made it come to fruition through their designs as built works. Zeki's very recent considerations have heightened resonance: "You may be shocked with what I'm about to say: I think artists are neuroscientists, but they know the brain in a different way" (Zeki 2019).

Part of the scope of our research is to highlight that very intuition, demonstrating its embedding in architectural production through evidence we believe is to be found and which we intend to bring forward. From an architectural theory and historiography standpoint, the possibility of a retrospective reading of both architectural theory and architectural production, as a result of the moment at hand, is most enthralling.

Indeed, as demonstrated with *Architecture and Embodiment* (Mallgrave 2013), confirmations and new revelations about the particularities of architectural experience can be extracted through a combination of existing and new areas of scientific inquiry, with the role of phenomenology of architecture and aesthetic theory highly reinforced here, as they established the groundwork through which dialogues between architecture and the neurosciences are now possible. It is our view that these confirmations and revelations are particularly interesting for architectural theory as an area of scientific inquiry. In our research, they are considered adjuvants in our search for evidence of experiential phenomena particular to architecture and instrumental in theorizing their underlying processes and components in a way that is methodologically and hermeneutically coherent throughout. Conversely, we argue that further hypotheses about experience may be theorized, from an architectural theory standpoint, to then be tested by the neurosciences—this is an exercise architects are in a uniquely privileged position to contribute to.

2. HYPOTHESIS AND RESEARCH QUESTIONS

Our research is a study, in the field of theory of architecture, about architectural experience in what we consider to be its artifacts—recognizing phenomena of embodiment within the materials particular to architecture. Therefore, *artifact* here designates *evidence of experiential phenomena*, and thus, in a way, evidence of phenomena of embodiment.

While we draw from the works of Steen Eiler Rasmussen, Christian Norberg-Schulz, and others—authors who produced some of the most successful observations on the subject of architectural experience, by theorizing and illustrating experiential effects vis-à-vis architectural settings, usually by means of specific isolated examples—we believe there is much to be found about architectural experience and its complexities within a single architectural production,

from authorial intention to *in situ* fruition. It should also be noted that, our research is not aimed at proposing the replacement of metaphors of expression about experience with new terminologies, but rather to draw from a (neuro)phenomenological understanding of a given component of experience, in order to recognize it within those metaphors. Moreover, a metaphor in itself may compose an artifact.

In our research, a necessary distinction is established between *the others* (non-authors, who experience a given architectural setting) and *the authors* (who propose a given architectural setting, who will experience said architectural setting from an intrinsically different position than that of non-authors)—as there are artifacts that clearly *belong* to the authors while others *belong* to the others. The idea that experience pertains to these two realms, that of *the authors* and that of *the others*, is, indeed, traceable to Álvaro Siza's and Rem Koolhaas's words, and while similar at first glance, nuanced hues about particularities of the architectural métier are detectable. Koolhaas (2012) proposes that "A building has at least two lives—the one imagined by its maker and the life it lives afterward—and they are never the same." While Siza (1992) posits, "Architectural creation is born of an emotion, an emotion urged by a moment and a place. The project, and the construction, demand the authors release themselves from that emotion, in a progressive distancing—conveying it whole and occult. From then on, the emotion belongs to the other(s)" (9).

Once evidence of the authorial intention is unveiled, is it observable as experiential phenomena *in situ*? Conversely, are the experiential phenomena (observed and expressed) traceable to the intention? As a comparative exercise emerges, what further details arise about architecture and (its) experience?

We seek to establish an interpretive study of Álvaro Siza's and Rem Koolhaas's approach to architecture as a lengthy, complex, and meandering exercise, which culminates in a fully accomplished authorial work delivered to others, ultimately, for their experience.

3. METHODOLOGY AND OTHER NOTES ABOUT AN ONGOING RESEARCH

Our research is designed to demonstrate the embodied nature of architectural experience in its artifacts. Thus, it is through evidence of experiential phenomena that the construction of our greater object of analysis is built by composing a long section through instances of architectural experience, it is then possible to venture into their expanded characterization and, quite importantly, to bring forward correlations between them.

Aspiring to a broader characterization of the authors' methods and resulting architectures, we are

focusing our attention on two examples, both in the city of Porto. *Museu de Serralves* (1991-1999) by Álvaro Siza, a museum of contemporary art within the grounds of an art deco house with a large gated park, and *Casa da Música* (1999-2005) by Rem Koolhaas/OMA, a concert hall in a consolidated area of the city, in what was once (and is now again) considered the second city center of Porto. These two cultural institutions played their role in what has been described as Porto's recent renaissance, helping revitalize a once rich and then dwindling local cultural scene (as it was in the latter part of the 20th century), with visible gravitational pull on a wider public, both local and international.

The demonstration of our hypothesis is built through the collection and analysis of a combination of materials, specifically directed at unearthing artifacts of embodiment as our navigational compass: by a retrospective reading of authorial materials, i.e. published materials and archival materials (some of which never before published), by collating a selection of existing materials, and by the structured collection of new *in situ* materials. The resulting greater object and ensuing analysis differ from previous studies in their *raison d'être*, in our particular considerations about these buildings, about these authors, and in a broader sense, about architectural experience.

The authors' archives are of paramount importance for our research. Architects make use of specific speculative models as methods of anticipation as they engage in rehearsals and simulations of a design later to become built architecture. We posit this prospective and speculative process results both from and in an *intention*. Regardless of whether this intention is consciously or not embedded in their designs, great architects propose, in effect, architectural settings for experience, honed and curated by a complex and painstaking articulation of architectural solutions with a programmatic problem. This is in line with what Le Corbusier (2000) suggested in 1945: that *ineffable space* is manifested as a result of the "efficiency of the [artist's] intentions whether consciously controlled or not."⁵ In his signature grandiose style, Le Corbusier continues, "[S]eized or elusive, these intentions nevertheless exist and are rooted in intuition, that miraculous catalyst of acquired wisdoms, assimilated, even forgotten. In a completed and successful work there are hidden masses of intentions . . ." (24-25).

Rather than sleek monograph illustrations and expensive display models, we selected not-meant-for-publication materials to inform our inquiry. We argue and demonstrate with selected examples that these are, particularly here, both a vehicle for and a result of the complexities of embodiment, playing a most significant role in shaping the experiential intention embedded

in these projects and successful as such, once their essence was translated into construction drawings and onto built architectural settings.

Similarly, we survey *the others'* experience, though here the first-person account is taken into consideration in a non-systematic manner. "[T]he study of mental phenomena is always that of an experiencing person", considered Varela (1996, 346). Indeed, Varela (1996, 344) championed the "first-person evidence" as fundamentally necessary for neuroscientific inquiry.⁶ Varela's championing of the first-person account as necessary for the neuroscientific inquiry, was the transformative proposal that gave origin to neurophenomenology. Several methodologies have derived and evolved from Varela's proposal. It is not yet clear or consensual whether these methodologies—such as the micro-phenomenological interview (Petitmengin 2006; Bitbol, Petitmengin 2017)—will provide the ultimate access to "disciplined first-person accounts", as Varela (1996, 344) intended. We consider both the spontaneous first-person account and semi-conducted interview—methodologies for the collection of narrations of experience not unknown to architectural theory, historiography, and critique. Moreover, artifacts of *in situ* fruition include but are not limited to narrations of experience.

It should be noted that, in the particular case of architectural experience, as considered in our research, the direct observation of an architectural setting and corresponding *in situ* experiential phenomena is as important a means for the identification of artifacts as is the first-person account. The criteria established for methodological orientation behind the choice of examples was set to ensure direct and wide access to observation of *in situ* experiential phenomena, a wide variety of archival material pertaining to the authorial process, and an array of materials about the buildings in the media, and more recently in social media. Therefore, easily accessible and highly documented examples were preferred. Buildings where access to *in situ* occurrences of experience without interference would prove challenging (i.e. private houses) were avoided, as it would render our research too reliant on narrations of experience without the possibility of pairing our direct observation without interference. The selected examples are intrinsically different in their authorial processes, programs, and configurations, while simultaneously similar in their local and international impact, with overlapping sets of visitors and public—characteristics which we consider to be of added value here.

Thus far, as the particularities of the evidence collected are emerging, pivotal moments of a more minute exactitude have been identified within the broader scale of the authorial process, and which have greatly shaped what has been observed *in situ*. These

minutiae will be brought forward as case in point on the correlations between the expected qualities of a given architectural setting embedded in the authorial intention and subsequent *in situ* experience. Additionally,

instances have been found in which purely managerial decisions have thwarted the buildings' full experiential potential—decipherable from the authorial evidence—by bypassing the architects' intentions.

ENDNOTES

- 1 Not a farfetched assumption, as Rasmussen (1959, 10) clearly expresses his position a few paragraphs down: "Architecture is a very special functional art; it confines space so we can dwell in it, creates the framework around our lives" (see endnote 5).
- 2 Unlike MRI, the fMRI (functional magnetic resonance imaging) detects blood flow fluctuations in the brain as a means to identify areas of increased neural activity as indicators of response to stimuli through directed task performance.
- 3 Positive outcomes may emerge from *neuroscience for architecture*, namely in the search for the *salutogenesis* of space and ways for architecture to address health and well-being related predicaments through its spatial and experiential qualities.
- 4 For more on the *hard problem of consciousness* see Francisco Varela (1996) and Kirchhoff, Michael D., and Daniel D. Hutto. 2016. "Never Mind the Gap: Neurophenomenology, Radical Enactivism, and the Hard Problem of Consciousness." Edited by Tom Froese, Sebastjan Vörös, and Alexander Riegler. *Constructivist Foundations* 11 (2): 302–30.
- 5 We have inserted the term *artist* here as it is in line with the previous paragraphs by Le Corbusier. It is worth noting that Rasmussen and Le Corbusier intersperse the cited texts with *architect* and *artist*, and *architecture* and *art*, as seemingly interchangeable terms (see endnote 1).
- 6 "The claim about appropriate levels of description between brain events and behavior is, of course, not new and rather uncontroversial except for those who are extreme reductionists. The novelty of my proposal is that *disciplined first-person accounts* should be an integral element of the validation of a neurobiological proposal, and not merely coincidental or heuristic information" (Varela 1996, 344, British English spelling in the original).

REFERENCES

- Bitbol, Michel, and Claire Petitmengin. 2017. "Neurophenomenology and the Micro-Phenomenological Interview", in *The Blackwell Companion to Consciousness*, 726–39. Chichester, UK: John Wiley & Sons.
- Kirchhoff, Michael D., and Daniel D. Hutto. 2016. "Never Mind the Gap: Neurophenomenology, Radical Enactivism, and the Hard Problem of Consciousness." Edited by Tom Froese, Sebastjan Vörös, and Alexander Riegler. *Constructivist Foundations* 11 (2): 302–30.
- Koolhaas, Rem. 2012. "The Invention and the Reinvention of the City: An Interview with Rem Koolhaas, by Paul Fraioli." In *Journal of International Affairs* 65, no. 2, (Spring/Summer): 113–119. Available at <https://jia.sipa.columbia.edu>.
- Le Corbusier. 1946. "L'Espace indicible". *L'Architecture d'Aujourd'hui*, N° Hors série "Art", Avril: 9–17.
- Le Corbusier. 2000. *Le Modulor et Modulor 2*. Paris: Fondation Le Corbusier / Birkhäuser.
- Loos, Adolf. 2007. "Architecture (1910)." In *On Architecture: Studies in Austrian Literature, Culture and Thought*, 73–85. London UK: Ariadne Press.
- Mallgrave, Harry Francis. 2013. *Architecture and Embodiment*. New York NY: Routledge.
- Neutra, Richard. 1954. *Survival Through Design*. New York NY: Oxford University Press.
- Norberg-Schulz, Christian. 1979. *Genius Loci: Towards a Phenomenology of Architecture*. 1st ed. New York: Rizzoli.
- Pallasmaa, Juhani, Harry Francis Mallgrave, Vittorio Gallese, and Sarah Robinson. 2015. *Architecture and Empathy*. Edited by Phillip Tidwell. 1st ed. Espoo: Tapio Wirkkala-Rut Bryk Foundation.
- Petitmengin, Claire. 2006. "Describing One's Subjective Experience in the Second Person: An Interview Method for the Science of Consciousness", *Phenomenology and the Cognitive Sciences*, 5, 229–69. Berlin, Heilderberg, New York: Springer Science & Business Media.
- Rasmussen, Steen Eiler. 1959. *Experiencing Architecture*. Cambridge MA: MIT Press.
- Robinson, Sarah, and Juhani Pallasmaa, eds. 2015. *Mind in Architecture: Neuroscience, Embodiment, and the Future of Design*. Cambridge MA: MIT Press.
- Semir Zeki, *Neuroscientist*. 2017. London, United Kingdom: Tern Television Productions.
- Siza, Álvaro. 1992. "Prefácio." In *Álvaro Siza Obra e Método*, edited by Jacinto Rodrigues. Porto: Civilização Editora.
- Varela, Francisco J. 1996. "Neurophenomenology - A Methodological Remedy for the Hard Problem I: A Cartography of Approaches." *Journal of Consciousness Studies* 3 (4): 330–49.
- Zeki, Semir. 2019. "Em Relação à Beleza, Os Artistas São Neurocientistas. Semir Zeki Entrevistado Por Isabel Lucas." *Público*, August 28, 2019.

MACHINE LEARNING FOR ARCHITECTS AND DESIGNERS: Implementing Machine Learning into the Digital Design Process

Adam Sebestyen
Vienna University of Technology
New Design University St. Pölten

Abstract: In 1962, engineer Douglas Engelbart proposed overlapping the creative mind with artificial intelligence to create designs which could not be created by either entity alone (Engelbart 1962). Today Machine Learning (ML) has entered the public consciousness emerging as an important tool in many industries. Architects should understand these tools to be able to create new and innovative design ideas to meet complex design criteria.

According to Hebron (2016) traditional design algorithms rely on the information programmed into the design software combined with a specific user input/workflow. These systems allow the computer program's behavior to be defined as a finite set of rules that will behave in a predictable manner and thus conform to the programmer's or user's intentions. In comparison ML can detect patterns inside observed workflow data and provide mechanisms for imparting experiential knowledge upon computer systems.

In the specific case of parametric design, rules are established by the user by defining a sequential step-by-step instruction set of geometrical operation tasks upon a set of input data. However, establishing these rules can be a time consuming and complex task. ML can help create those specific rules, if the user can define and provide the necessary input-data and desired output-data. This could lead to faster simulation and optimization methods, as well as the discovery of new parametric design rules.

This paper aims to break down basic ML concepts and proposes how they could be implemented in the architectural digital design process. The focus will be put on supervised machine learning as a tool in aiding and complementing parametric design tasks. A prototype project will be showcased.

The foremost aim of this paper is to lay out the hypotheses of how ML could be further implemented inside the digital design process.

Further, an overview will be given of basic ML and parametric design principles, as well as demonstrating the need for architects and designers to implement ML in their design workflow.

Keywords: Machine learning, artificial intelligence, computational design, digital design workflow

INTRODUCTION

Computer based design has evolved to a point where designers describe geometrical modeling processes, instead of using additive methods inside CAD software. This is done using parametric design, where a modeling process is broken down into individual sequential instruction sets. This method gives the user great flexibility when experimenting with design proposals and/or geometrical shape creation. However, the nature of parametric design requires a lot of idle time when updating or changing complex design processes. This can hamper the creative design process when designers must wait every time they update their design solutions. Further, new design methods or outputs require a new set of parametric design instruction sets. Figure 1 illustrates an example where the parametric design script takes roughly one minute to update.

Machine Learning (ML), as a subfield of Artificial Intelligence (AI), could be implemented inside the digital

design process in order to speed up the time needed when calculating complex parametric design workflows and, thus, let the designer work in a more efficient manner. Further, ML could give the designer the ability to explore more design ideas, as well as produce design outputs of higher complexity than would be possible with traditional digital design tools and approaches.

The overall work of my PhD thesis aims to implement ML in the field of digital design practice by developing new workflow methods for the exploration of geometrical outputs. This paper is a starting point for this research process and aims to do the following:

- Give an overview about different ML approaches, recap the basic parametric design principles and outline how implementing ML could help to reduce idle time during geometrical workflow tasks (Section 2).

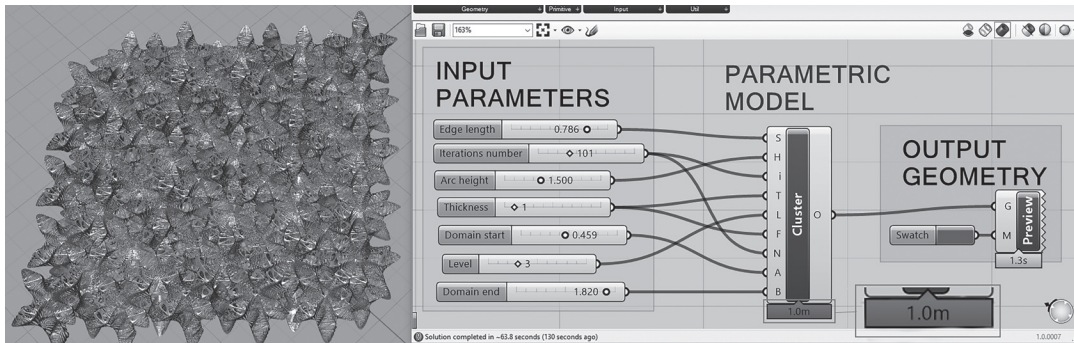


Figure 1: Example of complex parametric design script that requires about one minute to update after input changes. (Author 2019)

- Showcase concepts aimed to speed up the workflow of heavy computational parametric design tasks by implementing ML to let the computer detect patterns in design workflow data. Thus, the ML model would be able to predict the final output that stands at the end of a parametric design script. This would mean a direct conversion from input data to a desired digital design output, without the need to do any intermediary geometrical calculations (Section 3).
- Demonstrate this concept with a parametric facade prototype, where with the help of ML, the relationship of geometrical configuration to certain performance-measure outputs are taught to the computer (Section 3.4)
- Propose two further theoretical concepts of ML based methods to discover unknown parametric design workflows and outputs. One possibility discussed would be merging or blending different workflows. Also, the idea will be discussed of linking geometrical properties to data, in order to discover new and unknown geometrical configurations (Section 4).

1. BACKGROUND AND CONTEXT

In 1962 engineer and inventor Douglas Engelbart proposed the concept of the creative human mind overlapping with artificial intelligence to create designs which could not be created by either entity alone (Engelbart 1962). He envisioned a symbiosis between human and machine; thus, both becoming co-creators in a new and dynamic design process. The goal of such a system would be finding hidden or unknown design languages, methods, or concepts (Wood 2018).

Khean, Fabbri, and Haeusler (2018) argue that although ML has been an essential part in multiple industries and disciplines, in the field of architecture, it has a hard time gaining ground. They state that the field of architecture is "objectively one of the slowest industries to integrate with machine learning." Moreover,

they attribute this among other things to the fact that "machine learning expertise can be separate from professionals in other fields; however, this separation can be a major hindrance in architecture, where interaction between the designer and the design facilitates the production of favorable outcomes" (95). Cudzik and Radziszewski (2018) further back this notion, "Despite the growth of machine learning usage, the architectural practice still relies on a daily basis on computer aided drawing and building information modeling" (81).

Hebron (2016) explains how in the field of AI it is especially ML that works on the principle of identifying patterns in observed data, compared to traditionally used design algorithms, which rely on the information being programmed into the design software combined with a specific user input/workflow. These systems allow the program's behavior to be defined as a finite set of rules that will behave in a predictable manner and thus conform to the programmer's or user's intentions. Machine learning, on the other hand, provides mechanisms for imparting experiential knowledge upon computer systems. This lets the computer deal with fuzzier or less precise input data. For example, in the field of 3D geometrical design this suggests that instead of using an explicit set of rules or instructions to describe how geometry should be created or transformed, a machine learning algorithm could look for patterns within a set of sample behavior, in order to produce an approximate representation of the 3D modeling rules themselves. This presents a significant paradigm shift, not only in terms of how future architects and designers will interact with computers and design software but could also fundamentally question long standing principles such as basic design rules and human creativity.

Muklashy (2018) analyzed the potential impact of ML in the architectural field and argues that, although the architectural workload will dramatically change in the future, designers will be "finding more time for creativity while computers handle data-based tasks." He

acknowledges that those designers who are unwilling or unable to adapt “will have trouble pivoting from traditional roles.” But for those who see ML as “tools rather than obstacles (it) can lead (them) to freedom from the constraints of old models.” He further quotes Mike Mendelson, certified instructor and curriculum designer at the Nvidia Deep Learning Institute,

Computers are not good at open-ended creative solutions; that’s still reserved for humans, ... But through automation, we’re able to save time doing repetitive tasks, and we can reinvest that time in design.

He also cites Jim Stoddart of the Autodesk design research studio *The Living*:

We can still leverage the things that humans are really good at—the human intelligence, the creativity - but then also leverage the machine intelligence, the specific capabilities for computers to solve problems really quickly,... a hybrid approach that is actually better than what we’re able to do with one or the other separately. (Muklashy 2018)

Therefore, architects should start to understand and implement these tools inside their workflow to be able to create new and innovative design-ideas to meet complex design criteria. Furthermore, research linking the creative practice field and machine learning must be established to find future workflow- and workload-principles, as well as explore the ramifications of ML in the field of design practice.

2. MACHINE LEARNING IMPLEMENTATION IN PARAMETRIC DESIGN WORKFLOWS

2.1. CLASSICAL PARAMETRIC DESIGN APPROACHES

Tedeschi (2014) explains the evolution of computer-based design. He compares early CAD applications to the practice of drawing by hand on paper calling these methods an “additive process”, since independent signs of information are overlapped onto each other to convey meaning: “...the drawing is not a smart medium, but rather a code based on standards and conversations” (16).

Advanced CAD applications and parametric design environments let the designer establish relationships between different inputs and workflow steps (figure 2). Tedeschi calls this “algorithmic modeling” describing an algorithm as a “step-by-step procedure” performed by the computer “through a finite list of basic and well-defined instructions”. He states that an algorithm “is an unambiguous set of properly defined instructions” and that an algorithm “expects a defined set of input”. The benefit over the additive design process is that “algorithmic design enables the user to design a process rather than just a single object” (Tedeschi 2014, 22-25).

Although these design methods allow us to create designs not conceivable with classical additive

methods, this process can be very computational heavy and therefore often time intensive. A set of instructions acts upon input data, and in the case of digital design these instructions often entail multiple geometrical operations. This means that on every geometrical or numerical input provided into the algorithmic system, all instructions must be performed individually in sequential order. Therefore, multiple computational geometrical operations will require more time until the final instruction has been completed and the final output can be produced. Further changing just one input parameter requires the algorithm to recalculate all instructions tied to that parameter. In the end, this means that algorithmic processes which are either computational heavy or have a lot of input parameters will require a lot of time from the designer, especially if they wish to produce multiple possible outputs.

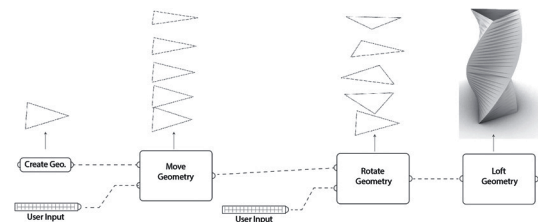


Figure 2: Diagrammatic parametric design process (Author 2019)

2.2. ML BASED PARAMETRIC DESIGN APPROACHES

Using a very broad breakdown, three ML concepts surface, all vastly different in their approach to problem solving and potential design related use cases (Maini and Sabri 2017; Geitgey 2018):

- **Supervised Learning:** These algorithms first must be trained by the user on a known/labeled dataset, teaching the computer what the desired output ought to be for a certain input. After sufficient training, the algorithm will be able to predict the correct outcome corresponding to previously unseen input data.
- **Unsupervised Learning:** Unlike supervised learning, in this case the system does not figure out the correct output but rather helps the user to find the underlying structure, patterns, or meaning in an unlabeled data-set. There is no information available helping the computer to be trained beforehand.
- **Reinforcement Learning:** This algorithm interacts with its environment through an agent. In the absence of existing training data, this agent learns from experience through a trial and error approach in combination with a reward or punishment system. This creates an AI that is eventually able to execute the correct behavior in a wide variety of situations.

I am proposing using Supervised Learning to reduce the time for live parametric model calculations, which will be achieved in two main steps: *training/building* the ML model and *deploying* the ML model.

In classical parametric design the user establishes rules, i.e., the script that acts upon input data, to produce an (geometrical) output: The user provides the input and rules, the computer generates the output. On the other hand for supervised ML the user would still have to provide the computer with input data, but instead of defining a rule-set to transform the data, the desired output data will be fed into the ML training algorithm. Providing the ML algorithm enough data-sets of input data (X) and corresponding desired output (y) would allow the computer to learn the correct relationship between input and output and thus find the corresponding rule-set. Figure 3 showcases how in classical parametric design the user has to provide input data and a rule-set in order to achieve an output, while in a ML based approach the user would have to define the input and desired output data in order to receive a rule-set. This can be especially useful if the needed rule-set is highly complex.

2.3. ML MODEL TRAINING AND DEPLOYING

The following is a theoretical overview regarding the necessary steps of implementing ML inside the digital parametric design process:

Producing Data for ML Training:

First, training-data must be created: To do so a parametric design script must be built. This script could either produce geometry as its output (parametric modeling process) or analyze geometrical properties (geometrical/performance analysis). In my prototype, which will be discussed later, Grasshopper¹ will be implemented for all parametric design tasks. Next, a multiple of randomized input data would be created and these inputs would have to run through the parametric design script. Afterwards, the inputs and the produced corresponding outputs would be recorded. This step of course could be a time intensive task since many

calculation circles through a potential heavy instruction set might be necessary.

Training the ML Model:

Next would be the training phase: The supervised ML model would be shown all the created input data together with their corresponding outputs. During the training, the ML algorithm should be able to find patterns in data-shifts from the inputs to the outputs. After training, a successful ML model would be saved.

This step could be time intensive too, depending on the amount of training data used and the specific training settings applied to the ML model. However, the idea is to have the process of generating training-data and building the ML model to be an automated one during which the designer has no active involvement. It would be possible to complete these processes overnight, when the designer is not working, or outsource them to cloud based supercomputers, which do heavy calculations very fast. In essence, the designer is shifting away the heavy time-load they usually must put in while actively changing and experimenting with a parametric design model, to a period when they would not be working.

Deploying the ML Model:

The trained ML Model will be implemented into the parametric design workflow. All components/ instructions used in the original algorithmic script are not needed anymore and can be disabled or deleted. All the user would have to do is connect new input data to the trained ML model. If trained correctly, the model would produce the correct output to the corresponding input data without the need for any time intensive step-by-step calculations. This would give the designer the ability to manipulate or completely replace the input data and receive geometrical or analytical outputs in a very short amount of time. This is possible because, rather than recalculating the entire sequential instruction set, all the ML algorithm must do is to predict corresponding output data according to the current input data.

In essence, ML gives the user the ability of a time tradeoff. Rather than spending time waiting for parametric models to be recalculated and updated during the design process, the user spends time beforehand on building and training an ML model. This step could be done by the computer mostly independently and autonomously. Afterwards during design time, the user will have a parametric tool that will be very fast and efficient to use even on slower computer systems. SideFX (2019) describes a similar approach for the simulations of erosion on digital landscapes: They trained an ML network to generate image data which the 3D FX software Houdini² could

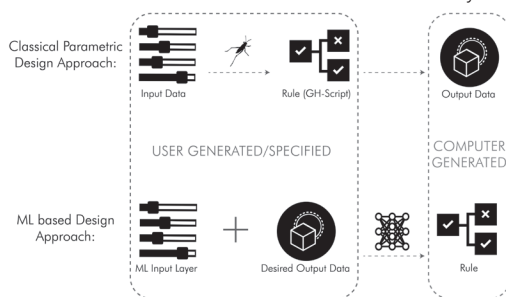


Figure 3: parametric design process (top) compared to ML based design process (bottom). (Author 2019)

interpret as a 3D landscape model. The information regarding the erosion data was part of the produced images. Compared to simulated 3D erosion models the results produced by ML were almost identical but around 50,000 times faster.

3. CONSTRUCTION OF ML BASED PARAMETRIC DESIGN PROTOTYPE: THE NECESSARY STEPS

3.1. DEFINING THE TASK

Preparing data to be usable by an ML algorithm can take a lot of time (Geron 2019). Therefore, thought must be put in beforehand to determine the exact parametric design task and its necessary in and output data.

Tedeschi (2014) describes multiple applications and outputs for parametric design. The most common ones can be summarized as geometrical creations or transformations where, through the parametric design process, geometry is created in a step-by-step process (See section 2.1). The output is almost always a geometrical object. Secondly, there are digital simulations such as cable or membrane simulations. At the output of such a simulation, one often finds a geometrical object as well. A different type of output can be of analytical nature, meaning geometry inside of a parametric design environment, is at some point analyzed and evaluated upon certain criteria, e.g. environmental or structural analysis. Often in parametric form-finding the output of this analysis is used in conjunction with a feedback loop to adapt the geometry and find an optimum based upon the analytical data (a.k.a. optimization).

Thus, we first have to determine the type of ML output (geometrical or analytical) and consider the dimensionality of the input and output data. Geron (2019) explains that ML tasks with multiple outputs are possible, however for basic ML models the user must define beforehand how many output values are expected from a certain amount of input values. For an analytical output this is not a problem, as long as

the tool always provides the same amount of output values for different input geometries. However, if the aim is to create geometry as output, it could be difficult to express different geometrical shapes always with the same number of numerical values. A possible solution to this issue would be to represent geometry in a fixed 3D voxel space (Wu et al. 2016). The same applies to the input data: Input data should always be of the same size and dimensionality.

With our proposed prototype we aim to teach the computer the relationship between the geometrical properties of a partial facade system with louvers with its radiation analysis and its light transmittance values.

Overall, there are two main objectives:

- It is hoped that the ML model will correctly learn this relationship, in order to make analytical predictions to a certain geometrical configuration much quicker than could be done through classical simulation.
- Further, it is the hope to utilize this learned relationship to have the ML model predict adequate geometrical configurations according to a user's prior definition of the desired analytical outcome.

For data creation and later ML testing, a Grasshopper script was created. This script mainly does two things: first it produces the facade system geometry based on eight input values; secondly it analyzes the average solar radiation received in kWh/m^2 as well as the percentage of the overall facade system occluded by solid louvers. Thus, in our system we have geometrical properties as input and analytical data as output. Figure 4 shows the parametric design model. The image in the middle shows the model of the facade and its visualized analytical radiation data. The left image shows all eight input values needed to describe the facade geometry; the right shows the corresponding two analytical output values which the script calculated.

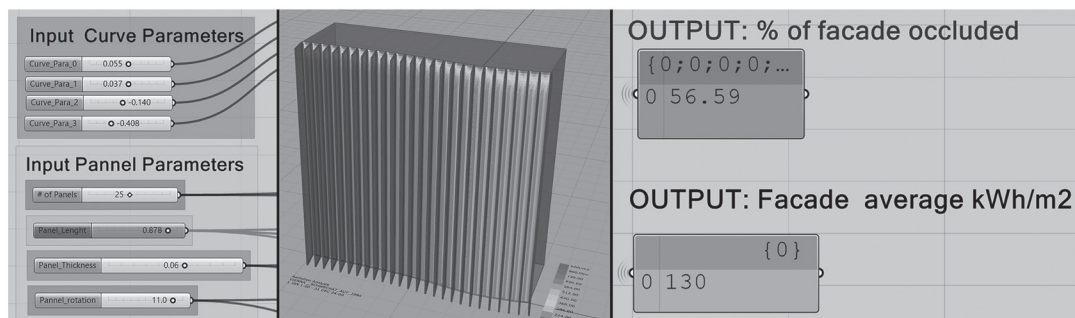


Figure 4: the parametric design script; Left: 8 input values; Middle: the geometrical facade model with visualized analysis; Right: 2 output values. (Author 2019)

3.2. CHOOSING THE RIGHT SUPERVISED MACHINE LEARNING MODEL

Maini and Sabri (2017) explain that there are two tasks of supervised machine learning in regard to the model's output: Regression and Classification. Regression models predict a continuous numerical value as output, while Classification models assign a label to an input out of a finite pool of possible answers.

A parametric design model producing either geometrical or analytical data is capable of an infinite number of possible outcomes, since every unique input usually produces its corresponding unique outcome. Therefore, implementing a *regression* ML model will be necessary.

Ray (2015) describes various regression models, which are used by ML to make predictions based on the input data. He states that the Linear Regression is one of the mostly widely known techniques. However, since a linear regression model can only find the linear relationship between input and output data, it will not be sufficient for a more complex (non-linear) ruleset. Geron (2019) explains how, through the technique of polynomial regression or Decision Trees regression, non-linear relationships between input and output data can be generated.

3.3. CREATING THE DATA-SET

The facade system consists of a variable number of louvers along a one-sided building envelop. The overall number, width, thickness, and rotation of the louvers can be set by the user (all louvers with same length, thickness and rotation). The one-sided building envelop can be described as a NURBS curve of degree three with its start and endpoint being ten meters apart. This curve can be described by a set of four numbers ranging between -1.0 and 1.0. Each of those four values represents the vertical distance from one of the curve's control points to its base line at 0. Setting all four curve parameters at 0 would produce a straight line, setting all four values to 1.0 would produce a curve that is arching upwards, setting all four values to -1.0 would produce a curve that is arching downwards, etc. Expressing the curve in numerical values is necessary since the ML model requires numerical values only to be trained. Overall, there are eight input variables to describe the facade's geometry.

For the outputs, the Plug-In Ladybug³ was utilized to calculate the radiation analysis of predefined points off the facade. To keep the overall process simple, all these values were summed and averaged in order to have a single value expressing the radiation analysis. Further, a custom Grasshopper script was set up to calculate what percentage of the building envelop will be occluded by the facade's louvers.

Therefore, each facade system is expressed by eight input values and produces two numerical output-values regardless of its overall geometrical shape.

Grasshopper was set up to produce all eight input values randomly, record those values, create the facade geometry, calculate its two corresponding analytical values, also record those two values, and finally save all the inputs and outputs inside a CSV-file. This process was autonomously repeated roughly 1700-times during a period of around 24 hours producing datasets for 1700 different facade systems. Figure 5 shows snapshots from multiple random variations of the facade system.

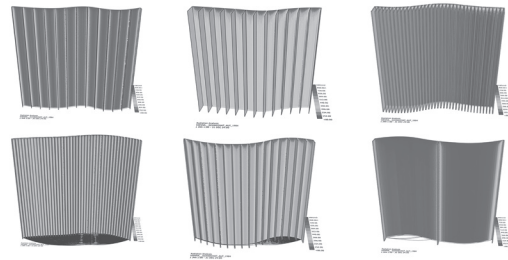


Figure 5: multiple random variations of the facade system used to create ML training and testing data-set. (Author 2019)

3.4. BUILDING THE MACHINE LEARNING MODEL

The Python programming language was used for data perpetration, the ML model's training, testing, and predicting progress. For combining the individual CSV-files and other minor data management tasks, the python library Pandas⁴ was implemented. For further data perpetration and the ML training and testing, the Scikit-Learn⁵ library was used.

After all the individual data-sets were combined into a single data-set, all inputs and outputs were extracted into their own data-set (X for input; y for output). Both X and y data-sets were split into training and testing sets (X_{train} , X_{test} , y_{train} , y_{test}) with the training set amounting to about 85% of the overall data. The training set would be used to train the ML model and the testing set would be used to evaluate the performance of the ML model afterwards. Both training and testing input sets were numerically scaled so all their values would fit into the domain from 0 to 1. According to Geron (2019), many ML models require their input data (features) to be scaled and centered.

Two different ML Models were trained, in order to predict different outcomes and perform different tasks:

- For the first ML model, using Scikit-Learn's Random Forest Regression Model we trained with X_{train} as input data and y_{train} as output data. Implementing the method of grid-search let Scikit-Learn find good settings for the ML model. The most promising

model produced by the grid-search was saved for later testing. Training a single ML model took around one second. Implementing grid-search took up to two minutes, if the computer was tasked to search among twenty different possible ML setups. Geron (2019) points out that for Random Forest models it is not necessary to provide the algorithm scaled data for training. Therefore, the un-scaled data was used. Nevertheless, it is good practice to produce a scaled data-set as described above in order to be able to test models other than Random Forest (or Decision Tree). However, in our case Random Forest Regression produced the best results. The idea was to implement this model, replacing the slow analytical tools running inside Grasshopper in the hope of quickly producing reliable analytical predictions useable during the early stage design process.

- For the second ML model, training inputs and outputs were *reversed*, meaning that analytical output data (y_{train}) was fed into the ML model as its *inputs*, while the eight parameters describing the geometrical properties of the facade (X_{train}) were used as the ML model's training *outputs*. The hope behind this method of training was to produce an ML model that can predict reliable geometrical input data, if the user specifies a desired analytical value *beforehand*. This approach could in theory be applied as an optimization method. Scikit-Learn's Random Forest Regression was used for training the model. As mentioned earlier, it does not require feature scaling. In this case, implementing an ML method not relying on feature scaling should have an advantage when deploying the model, since if a model is trained with scaled data, it also requires scaled data for prediction making. For the first ML model this would not be difficult to do since we as the user set the minimum and maximum values of our parametric design script inputs and thus can easily produce scaled input data. However, since the analytical output data used as input training in the second ML model is not bound by the user, it would be difficult to produce accurate scaled data since we can never know the true minimum and maximum values. A workaround would be to create a sufficiently large data-set with the largest possible wide analytical data spread, and use these values to produce feature scaling.

3.5. TESTING AND EVALUATING THE ML MODEL'S PERFORMANCE

Since 85% of the overall data was used for training both ML models, we were able to use the other 15% for verifying the results:

The first ML model (geometrical property as input, analytical data as output) ended up with a root-mean-squared-error (RMSE) of about 7.1, which is a promising score considering the facade radiation output value ranges from values 23 to 760 and the percentage of facade occlusion from 0 to 100. Using the testing set, for all individual predicted output instances the absolute difference was calculated from the prediction to the true value. For the radiation prediction the average difference was 6.6 points with the biggest difference being 41.1 points. For the occlusion data the average difference from prediction to true value was around 3.1 points with the maximum difference measured being 16.5. Both measurements indicated reliable predictions with the radiation prediction performing somewhat better (figure 7).

The second ML model (analytical data as input and geometrical data as output) achieved a RMSE score of about 2.9. Although it might appear that this model performs more reliably than the first one due to its lower score, this might not be necessarily the case. Most inputs defining the facade geometry exist on a rather small numerical domain. For example, the numerical range of the curve parameters is 2.0, or the numerical range of the louvers' length is 1.0. Further, a geometrical configuration does not necessarily exist for every analytical input specified by the user. Nevertheless, it seems clear that the algorithm was also able to establish a relationship between the analytical outputs and the geometrical input data. Calculating the individual differences from all the test data confirms this notion. The average difference for the curve parameters was around 0.5, which is quite a lot considering the overall range is 2.0 (figure 6). However, the ML model performed much better on the last four parameters describing the louvers' amount, orientation, and dimensions. This might be an indication that the curve parameters are not as decisive for the overall analytical performance of the facade than the other four parameters.

However, it must be pointed out that this method of testing cannot be truly compared to the testing metric of the first ML model. For the first ML model there are always two true analytical values linked to the geometrical facade properties. However, for the second ML model it could be possible that the geometrical configurations predicted by the script might produce similar analytical results as the true geometrical properties, although the predicted and true values do not match. Therefore, those predicted geometrical properties would have to be reinserted inside the Grasshopper script to assess the model's overall reliability. This slow process would need to be repeated multiple times to truly score the model's accuracy

and is outside the scope of this paper (However a few promising verification runs were conducted as described below).

Next, we tested both ML models in conjunction with Grasshopper and new and unseen user provided data:

In multiple runs, the geometrical input data for the facade were set by the user. These inputs were manually fed into the first ML model inside the python programming environment. Simultaneously, the analytical calculations were performed inside Grasshopper. The actual simulation took about one minute inside Grasshopper while the prediction making process using the trained ML model was instantaneous. Just like the RMSE score had suggested, the difference between the actual values and predicted ML values was small and confirmed the differences measured inside the test data. Figure 7 on the left-hand side shows the

	dif. cur_p1	dif. cur_p2	dif. cur_p3	dif. cur_p4	dif. amount	dif. length	dif. thickness	dif. rotation
count	262.000000	262.000000	262.000000	262.000000	262.000000	262.000000	2.620000e+02	262.000000
mean	0.527671	0.534246	0.501084	0.533279	3.823285	0.121208	9.814101e-05	3.826033
std	0.318730	0.318682	0.340551	0.341991	4.178787	0.124596	1.094304e-03	4.592382
min	0.001169	0.001169	0.000659	0.010859	0.000840	0.000105	6.800116e-16	0.003332
25%	0.264428	0.272484	0.214474	0.233553	1.136168	0.033625	8.129504e-08	0.428656
50%	0.512230	0.514465	0.445153	0.497243	2.368519	0.060223	1.514631e-07	1.901939
75%	0.767923	0.776981	0.778427	0.805437	5.128906	0.153243	2.174302e-07	6.460357
max	1.451810	1.451810	1.464245	1.452976	26.643750	0.731154	1.731188e-02	24.800396

Figure 6: testing second ML model: test data information regarding absolute difference between prediction and true values. (Author 2019)

	Dif. In Average_kWh/m2	dif in %_occluded
count	262.000000	262.000000
mean	6.561556	3.057167
std	6.452155	2.766461
min	0.005556	0.000000
25%	1.881597	0.800490
50%	5.161806	2.244312
75%	9.154514	4.795035
max	41.129167	16.457875

Figure 7: testing first ML model. Left: test data information regarding absolute difference between prediction and true values; Right Top: true Grasshopper calculations; Right Bottom: predictions for the GH data-set above. (Author 2019)

Output Values specified by user	INPUT Values Predicted by ML	OUTPUT produced by predicted values
(0)	(0)	Facade average kWh/m2
0 130	0 0.066	0 123
1 50	1 0.066	% of facade occluded
	2 0.032	0 0.000000
	3 -0.652	0 0.000000
	4 33	0 0.000000
	5 0.556	0 0.000000
	6 0.07	0 0.000000
	7 8.5	0 0.000000

Figure 8: testing second ML model. Top: the user specified analytical values, the geometrical input values predicted by the ML model and the resulting true analytical values; Bottom: The ML input and prediction within Python. (Author 2019)

difference scores calculated using the test data, as well as the prediction and true score inside Grasshopper.

Since this method achieved reliable information, with a degree of error that seems acceptable during early design phase at a fraction of the time compared to the true simulations, it seems appropriate to do further testing and develop this method more fully in the future.

Assessing the second model is not as trivial as the first. Nevertheless, in the few test runs the predicted geometrical configurations seem to provide reasonable predictions for their targeted analytical performance. In combination with the test data evaluation, this hints to the ML model being able to also recognize the relationship from analytical output data to geometrical input data and justifies a more in depth research of this topic in the future. Figure 8 illustrates an example, where the user was looking for a facade system with the analytical scores of 130 kWh/m² and 50%. The predicted geometrical properties ended up producing a facade system with the analytical values of 123 kWh/m² and 49.4%.

4. IMPLEMENTING ML FOR EXPLORATION OF NEW DIGITAL DESIGN WORKFLOWS AND GEOMETRICAL SHAPE EXPLORATION

4.1. BLENDING MULTIPLE DIGITAL DESIGN WORKFLOWS IN ORDER TO DISCOVER NEW WORKFLOWS

Maini and Sabri (2017) explain that "linear regression is a parametric method, which means it makes assumptions about the form of the function relating X and Y" (22). Through the implementation of mathematical concepts like a cost function or loss function supervised machine learning can recreate an unknown function by just looking at the function's inputs and outputs. For a function with a one-dimensional input (X) and one-dimensional output (y) using linear regression we would produce a line of best fit. "In three dimensions we would draw a plane, and so on with higher-dimensional hyperplanes" (Maini and Sabri 2017, 22). This is what our ML model described in the previous section would have done if implementing a different ML model than Random Forest Regression (or Decision Tree) like for example a linear regression: In this case, it would have recreated a function by producing a hyperplane with an 8-dimensional input and a 2-dimensional output (and of course for the second ML model a hyperplane with a 2-dimensional input and an 8-dimensional output). Ray (2015) describes more complex regression methods, like the Polynomial Regression, which in 2D space would produce a curve that fits through the data points instead of a line.

Machine learning enables us to express multiple sequential parametric geometrical workflow operations as a single, higher dimensional function. This could be used to potentially discover new forms of geometrical workflows.

The idea is to create two or more geometrical workflows. Each workflow is represented in multidimensional space by its own workflow function. As long as these multiple functions occupy the same multidimensional space, they can be added, subtracted, or blended into each other thus creating new, and eventually unknown geometrical workflows and eventually unpredictable geometrical outputs. Figure 9 demonstrates this in a simplified version in a 2-dimensional space: Workflow Function 1 and Workflow Function 2 exist in the same dimensional space. Therefore, it is mathematically easy to calculate their blended state and thus create a new workflow function.

It is important to note that both workflows do not have to perform the same or similar geometrical operations. They can be vastly different from each other, as long as their input and output dimensional structure are identical.

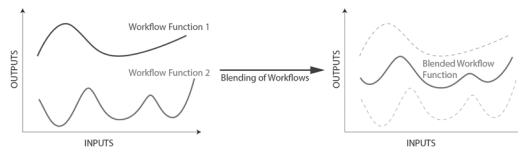


Figure 9: Blending of two 2D workflow functions into new workflow function (Author 2019)

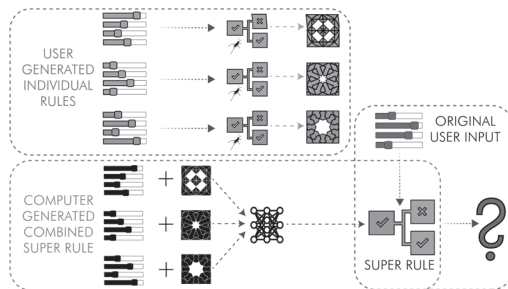


Figure 10: Using ML to combine three individual rule-sets into a single complex super-rule (Author 2019)

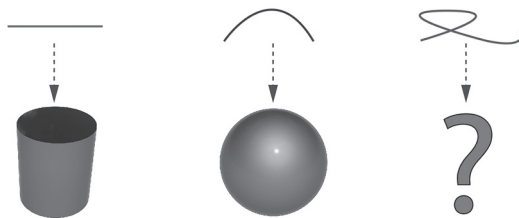


Figure 11: Linking the shape of a curve to 3D geometrical objects (Author 2019)

Figure 10 takes this concept a little bit further: The idea is to combine multiple, individual, and independent rules (parametric design scripts) into a super-rule. For each of the three rules input and output parameters are created just as in our prototype described in the chapter above (again it is important that all three rules have the same amount and dimensionality of input and output data). Instead of training data-sets derived from a single rule individually, all data-sets would be fed into the *same* ML model. This would create the super rule a complex combination of all individual rule-sets.

4.2. RELATING GEOMETRICAL PROPERTIES TO DATASETS IN ORDER TO DISCOVER NEW GEOMETRICAL CONFIGURATIONS

The paragraph above describes a theoretical method of combining multiple workflows in order to create new ones. A somewhat similar approach could be used within a single workflow function to discover new geometrical properties. In classical parametric design the input geometry is inevitably linked to the output geometry. We could also call the output a geometrical evolution of the input—one being the first link in a chain and the other the last link in the same chain.

Machine learning lets us link data that are usually not related. For example, we could easily link the pixel information in an image to the amount of curvature of a surface, or the current temperatures measured in all districts of the city of Vienna to the voxelization density of a mesh geometry. Surely relating data can also be done by traditional programming or parametric design; however, these rules of relationship would first have to be defined/programmed by the user. As Maini and Sabri (2017) explain with machine learning we can "... build models [to] predict [outputs] without having explicit pre-programmed rules and models" (9).

This means that the user would have to provide the ML model with a single input data-set and relate it to a desired state of a geometry. Afterwards they would repeat the same step with an altered input data-set and also an altered geometrical state. This can be repeated a couple of times and afterwards the model would be trained. Now the user can feed new input data into the trained ML model, which logical output would be very difficult for a human to predict. However, for the algorithm it will be very easy to produce the unexpected, however correctly corresponding geometrical result. This could be a useful tool in the creation of unknown complex geometrical configurations.

Figure 11 demonstrates this on a simplified version: If a red straight curve would be linked to the geometrical shape approximating a cylinder and a bend blue curve a sphere, what shape would be linked to the looping green curve?

This method has two clear advantages compared to classical parametric modeling:

- As described in section 2.2 training an ML model to perform geometrical operations could potentially save the designer a lot of idle time, especially with complex operations.
- It would be easy to link datasets to geometrical outcome since no explicit rule-set has to be defined by the user but rather desired geometry output states. Further, it would also be easy to link input data to geometrical parameters of different dimensionalities.

CONCLUSION

In this paper, I discussed the potential for implementing supervised machine learning performing regression to create new workflows of digital design. The output could be the creation and/or modification of complex geometries or sped up analysis or optimization tools. Implementing established parametric design approaches to create training data for ML models could be a potential time saver for the designer while they are in the process of exploring geometrical transformations. This could lead to more and complex geometrical experimentations in the field of design studies and creation.

An early prototype was created, training one ML model to predict analytical data based upon input geometry of a facade system and training a second ML model to predict reasonable geometrical configurations capable of producing similar analytical results to those specified by the user beforehand. Both prototypes produced promising results, so future exploration into the topic seems viable.

Nevertheless, the argument could be made that the relationships between the prototype's eight input data values and two output performance scores is not very complex and the workload of producing the data-sets does not justify the end results. Therefore, future focus should be put on more complex parametric relationships with a significant higher amount of input and output values; this could also include entire geometrical configurations as ML outputs. For the current ML model training, a Random Forest model was used. This was fast and sufficient, however for more complex future tasks it seems reasonable that a more complex ML model setup is necessary, such as a deep neural network. ML library *Keras*⁶ could potentially provide the ability to create such ML models specifically tailored towards complex geometrical workflow operations.

Besides improving and building upon the existing prototype, time should eventually be dedicated towards exploring the theoretical possibilities discussed in section 4.1 and 4.2: This would be the exploration of blending multiple geometrical workflows into each other, thus creating new and unexpected workflows. In addition research will be dedicated to the topic of linking multidimensional data to geometrical object states, in order to discover unknown states.

ACKNOWLEDGMENTS:

Credit must go to my department colleague *mgr. inż. arch. Jakub Tyc*, who produced all the Grasshopper scripts necessary for the facade performance analyses. He further supported me during the creation of the facade system and the data recording process.

Credits to the icon artists: *akash k; Trevor Dsouza; priyanka; Chameleon Design; Lluisa Iborra*.

ENDNOTES

- 1 www.grasshopper3d.com
- 2 <https://www.sidefx.com/products/houdini/>
- 3 <https://www.ladybug.tools>
- 4 <https://pandas.pydata.org>
- 5 <https://scikit-learn.org/>
- 6 <https://keras.io>

REFERENCES

- Cudzik, J., Radziszewik, K. 2018. *Artificial Intelligence Aided Architectural Design, Proceedings of the 36th eCAADe Conference - Volume 1*, Lodz University of Technology, Lodz, Poland, 19-21 September 2018, 77-84 Available at: http://papers.cumincad.org/cgi-bin/works/Show?ecaade2018_139
- Engelbart, D. C. 1962. *Augmenting Human Intellect: A Conceptual Framework*. Menlo Park: Stanford Research Institute. Available at: <https://doi.org/10.21236/ad0289565>.
- Gatys, L., Ecker A., and M. Bethge. 2015. "A Neural Algorithm of Artistic Style." *Journal of Vision* 16, no. 12: 1-16. <https://doi.org/10.1167/16.12.326>.
- Geitgey, A. 2014. "Machine Learning Is Fun! Medium." Accessed November 2019. <https://medium.com/@ageitgey/machine-learning-is-fun-80ea3ec3c471>.

- Geron, A., 2019. *Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow: Concepts, Tools, and Techniques to Build Intelligent Systems*. O'Reilly Media.
- Hebron, P. 2016. *Machine Learning for Designers*. Sebastopol, CA: O'Reilly Media. <https://www.oreilly.com/library/view/machine-learning-for/9781491971444/>.
- Khean, N. Fabbri, A. and Haeusler, M. 2018. *Learning Machine Learning as an Architect, How to? Presenting and evaluating a Grasshopper based platform to teach architecture students machine learning*. in Kępczyńska-Walczak A., Białkowski S. (ed.), computing a better tomorrow - 36th eCAADe, Lodz, Poland, pp. 95 - 102, presented at 36th eCAADe conference, Lodz, Poland, 19 September 2018 - 21 September 2018
- Maini, V., and Sabri, S. 2017. *Machine Learning for Humans*. https://www.dropbox.com/s/e38nil1dnl7481q/machine_learning.pdf?dl=0.
- Miller, N. 2018. "New Machine Learning Examples with LunchBoxML." *Providing Ground*. Accessed November 2019. <https://provingground.io/2018/03/12/new-machine-learning-examples-with-lunchboxml/>.
- Muklashy, W. 2018. "How Machine Learning in Architecture Is Liberating Designers." *Redshift by Autodesk*. Accessed November 2019. <https://www.autodesk.com/redshift/machine-learning-in-architecture/>.
- Ray, S. 2015. "7 Regression Types and Techniques in Data Science." *Analytics Vidhya*. Accessed November 2019. <https://www.analyticsvidhya.com/blog/2015/08/comprehensive-guide-regression/>.
- SideFX. 2019. "Machine Learning Data Preparation." *SideFX*. Accessed November 2019. <https://www.sidefx.com/tutorials/machine-learning-data-preparation/>.
- Tedeschi, A. 2014. *AAD Algorithms-Aided Design: Parametric Strategies Using Grasshopper*. Brienza: Le Penseur Publisher.
- Wood, H. 2018. "The Architecture of AI." *Medium*. Accessed November 2019. https://medium.com/@hw_/the-architecture-of-ai-a872c520f19c.
- Wu, J, et, al. 2016. "Learning a Probabilistic Latent Space of Object Shapes via 3D Generative-Adversarial Modeling." Accessed November 2019. <https://arxiv.org/abs/1610.07584>

TERMINOLOGY AND GEOMETRY: Evolution of Chinese Traditional Architectural Drawing

Lina Sun
The Bartlett School of Architecture

Abstract: Chinese traditional architectural drawing possessed a unique set of terminologies and geometric principles that were entirely distinguished from the Western Euclidean geometry, under the category of *tu* (the Chinese character for drawing). This paper etymologically and geometrically investigates the evolution of Chinese traditional drawing, from around the Tang (618-907 CE) and Song (960-1279 CE) Dynasties to the early modern period in the twentieth century. The etymology analysis centers on the terms *di pan*, *shi* and *yang*. The geometrical analysis deconstructs the composition of a selected drawing in the *Yang Shi Lei tu* archives in the Qing Dynasty (1636-1912 CE).

By doing so, this research reveals that the terminologies corresponding to different geometrical forms respectively indicate associations between architectural drawing and the philosophy of Chinese cosmology, and the arrangement of the geometrical forms in the visual picture plane facilitates expressions of the concepts of space and position in geometrical cosmology. Moreover, the architectural *tu* itself as an entity situating in between the technical *tu* tradition and painting tradition, developed architecturalization of pictorial languages.

Keywords: Chinese traditional architectural drawing, *tu*, terminology, geometry, cosmology

INTRODUCTION

This paper is situated in a broad speculation on the development of ancient Chinese architectural drawing. Nowadays, modern Chinese architectural drawings use Western Euclidean geometry and the corresponding terminologies. While the ancient *tu* (圖,¹ the Chinese character for drawing) fully accommodate different terminologies and geometries,² they have developed and evolved as well. The motivation for this development is the underlying cultural intentions. Terminologies and geometry, the two aspects of expression, are the products of the translation from intentions into drawings. In contrast, expressions reflect intentions. My main thesis in this article is to reveal the cultural intentions of *tu* by analyzing the expressions, referring terminologies, and geometry, in order to understand their development.

Research in the fields of Chinese *tu* (Behr 2007; Bray, Dorofeeva-Lichtmann, and Métaillie 2007; H. Wu 2007; Golas 2014) and painting (Rowley 1960; H. Wu 1989; Chung 2004; Barnhart et al. 1997; Zou 2011) has established a good foundation for this study. The abundant archive of Chinese architectural drawings revealed by other research (The National Library of China etc 2004; Ota 2005; Liu 2006; The National Library of China 2016, 2017, 2018) has made this research possible. However, several of the extant studies on Chinese architectural drawings have shown the existence of a vital gap. Studies that aim to show all the Chinese architectural drawings provide abundant archives including summarizing the terminologies and

drawings according to dynasties, while lacking a core analysis on the motivation for such development (J. Wu 1988; Liu 2006). The other situation is that researchers have combined drawings and other images, including buildings, together as their research objects when trying to analyze certain problems, as in Wu's research on the psychoanalysis of the Chinese visual tradition (C. Wu 2004). Further, architectural drawings are used widely as evidence for research on architectural history or restoration of buildings, such as the research on the largest archives of China, the *Yang Shi Lei Tu* (Wang and Zhang 2008; Wang and Zhang 2009; He and Shi 2013). Few studies have examined the development of architectural drawing as a whole and the motivation behind such development, or investigated the relationship between technical *tu* traditions and painting traditions.

The development of Chinese ancient architectural drawing can be divided into two stages. The first stage, which I will call the early informative *tu* stage, accommodated *tu* as a general concept, and *tu* related to construction drawing was composed without differentiation from other technical drawings and in simple lines together with text. The second stage started from around the Tang (618-907 CE) and Song (960-1279 CE) Dynasties, when architectural drawings were distinguished from other *tu* in both terminologies and geometry. It lasted until the early modern period, when Chinese architectural drawing completely adopted western drawing terminology and geometry.

This research focuses on the second stage and etymologically and geometrically investigates the evolution of *tu*. It reveals the denotation and connotation of the terminologies and situates the geometry of architectural drawing in the visual traditions between *tu* and painting. By doing so, this article argues how architectural drawing developed from the early *tu*, and then accomplished and distinguished itself from other technical *tu* while still embracing the cosmological geometry.

1. THE DIFFERENTIATION OF THE TERMINOLOGIES

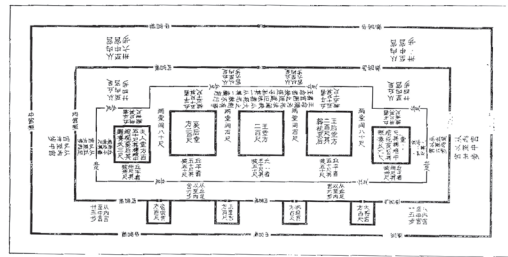
The formal differentiation and multiplication of the terminologies related to architectural drawing was first documented in the earliest known building manual of China, the *Ying Zao Fa Shi*, first published in 1103 in the Northern Song Dynasty (960-1127 CE), and the terminologies were widely used for a very long period. Before *Ying Zao Fa Shi*, some differentiation of terms related to *tu* had appeared in Chinese texts in the Tang and even earlier periods. The *Yang Shi Lei tu* archives from the Qing Dynasty (1644-1912 CE), the last and largest collection of drawing documents before the modern period in China, possess the same system of terminology. In the modern architectural journals, *The Builder* and *The Chinese Architect*,³ the terms still appeared on occasion, until they were completely replaced by terminologies translated from Euclidean geometric drawings in the twentieth century.

The terminologies included those that referred to the general concept of drawing and others related to the specific type of drawing. *Yang* (樣) and *shi* (式) are used to represent the general meaning of drawing in vocabulary and they are often put together or used in collaboration with *tu*, such as *yang shi*, *shi yang*, *tu yang*, and *yang tu*. The terminologies of *di pan* (地盤), *zheng Yang* or *li yang* (正樣 or 立樣), and *ce yang* (側樣) refer to the specific drawings.

In this part, I focus on analyzing the term *di pan* and the terms *yang* and *shi*. I argue that there are different ontologies and connotations between and among these three terms. This acknowledgement of the terms etymologically challenges the prevalent bold separation and understanding of *di pan*, *li yang* and *ce yang* as the three views of a building, comparable with the terms 'plan', 'elevation', and 'section' in Western Euclidean geometry.

1.1. DI PAN: THE CONNOTATION OF COSMOLOGY

Of all these terminologies, the term *di pan* inherited and even strengthened the connotation of the early *tu*, representing the plan of the building, which means the arrangement of the building on the site, and symbolizing the spatial concept of cosmology, both in the sense of terminology and in geometrical forms.



图一〇 昭阳宅图卷本

Figure 1: Line illustration of Zhaoyu *tu* (Yang 1987)

The *di pan* drawing style draws the plan of the buildings in the same way as the *tu* represents them. Although *tu* could function as a general concept of the representation of all the forms of drawing, *tu* drawing depicts and describes the arrangement of the buildings on the site, as in the drawings of *Zhaoyu tu* (Yang 1987, 171; Steinhardt 2002, 29)⁴ in the Warring States period (475–221 BCE) or in the description text of the classical city plan⁵ in *Zhou Li* compiled in the Warring States period. 'Plan' is the basic meaning in the terminology of *tu* as well. *Di pan* drawing was used to refer to the plans of buildings in the drawings of both *Ying Zao Fa Shi* and *Yang Shi Lei*.

Meanwhile, the geometry in *di pan* drawing structured the picture plane using the same logic as the early *tu* drawings. First, *di pan* drawings are composed in an informative way, like the early *tu*, using simple lines, rectangular frames and text as the signifiers of the components. Second, the spatial concepts of cosmology, direction, position, and proportion are the continual focus in the complex drawings of *di pan*. The four positions are interpreted multiple times and the lines are all drawn in strict proportion.⁶

As well as sharing the same geometrical language as *tu*, the etymological connotation of the term *di pan* itself strengthens the connotation of *tu* in the meaning of 'plan'. The original meaning, 'site of the earth', and the rhetorical meaning, 'foundation', form the epistemological context of acknowledgement of the term *di pan* as the plan of a building. For instance, *di pan* in this sentence—"After Zhuge di's enthronement, he sent a messenger, Ke lun yin, to offer a fire bead which looked like water essence (to the Tang central court) from the site (*di pan*) of the Luo cha kingdom"—in the *Tong Dian*,⁷ written in 801 CE in the Tang Dynasty, means 'site of the earth'. Accordingly, the plan—the 'site' occupied by the building—is the *di pan* of the building.

The rhetorical meaning of *di pan* as the root and foundation of the knowledge and principle indicates that *di pan* is the plan—the foundation for constructing a building and the foundation of other drawings, such as

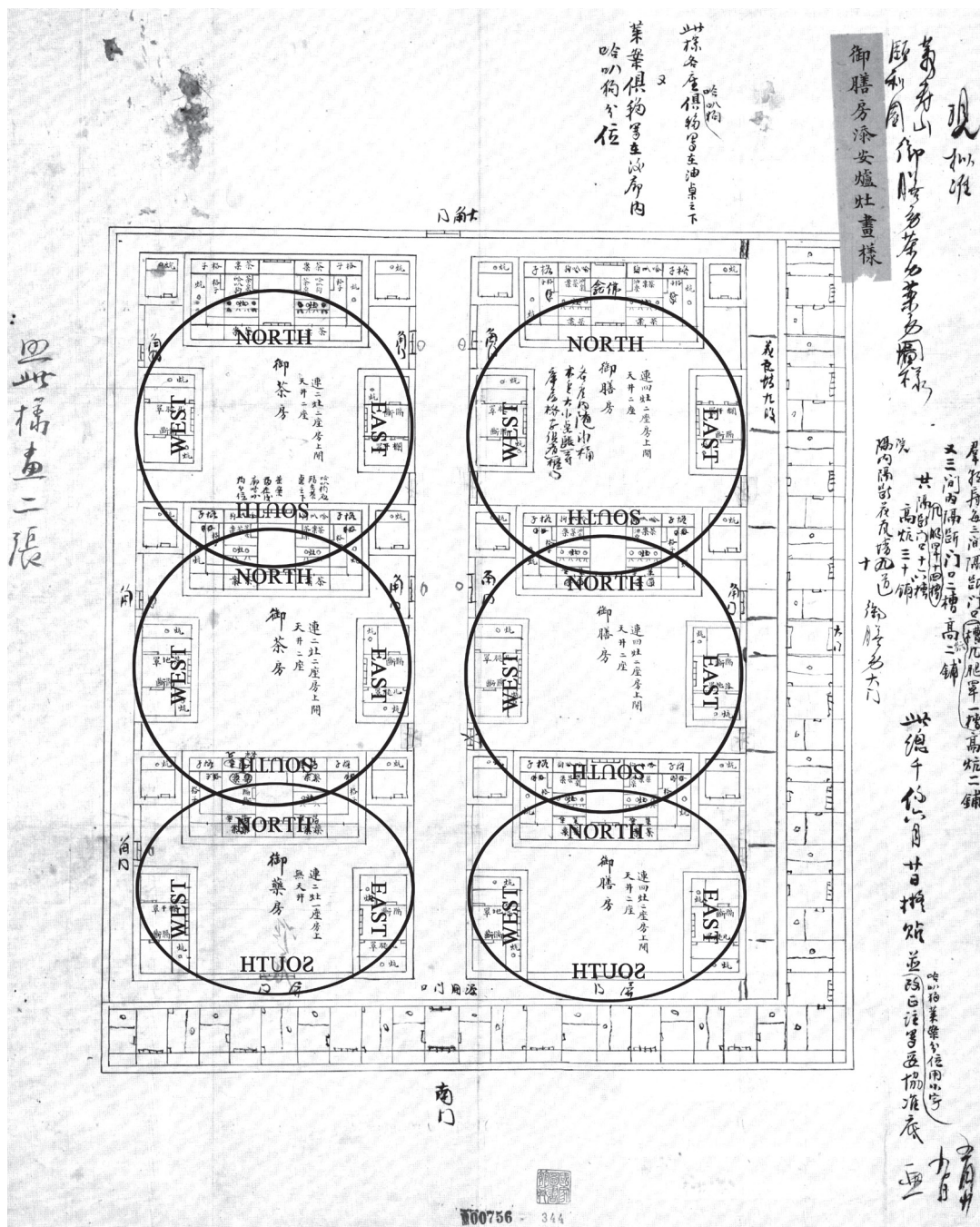


Figure 2: Di pan tu of Yu Shan Fang in the Summer Palace (©The National Library of China). (The base drawing reproduced from The National Library of China 2018).

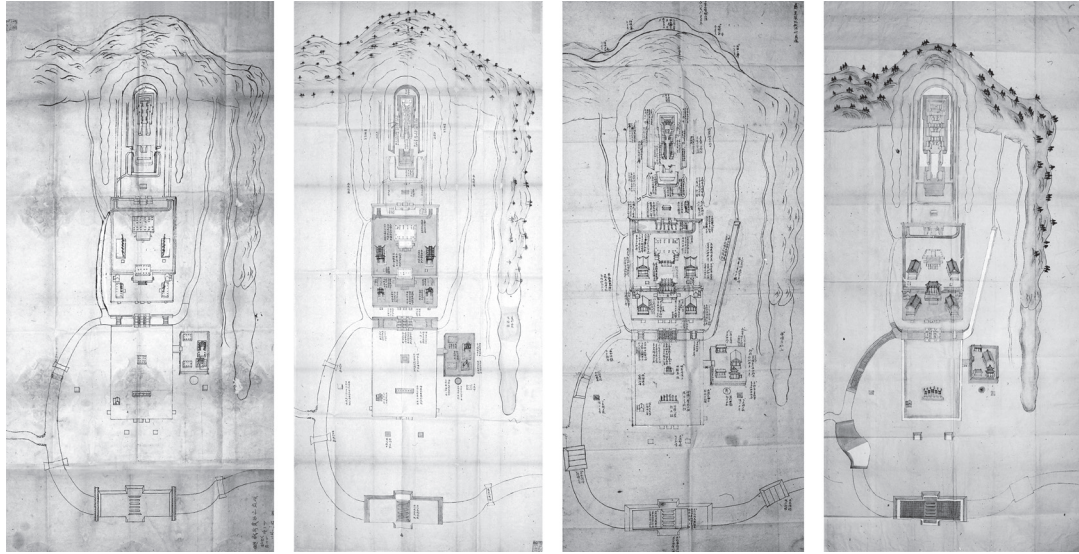


Figure 3: A series of drawings of Hui Mausoleum in Yang Shi Lei tu archives (©The National Library of China). (The National Library of China etc 2004)

in the text of “Gaining the foundation of the knowledge, is *di pan*. Just like if a person wants to build a house, he must first construct a strong foundation and then build a house on the top” in the Confucian text of *Zhu Zi Yu Lei*,⁸ edited in 1270.

The *di pan* drawing is indeed the foundation of others in a series of drawings. A series of drawings of the *Yang Shi Lei tu* for the mausoleum of the Qing emperors, which not only indicated the construction of buildings but also the drawing sequences (Wang 2014), indicates the foundation of the *di pan tu*. The series of drawings starts with several of the *di pan tu*, from the simple text and frame as a signifier to the more complex version using a combination of *di pan tu* of single buildings due to the development stages of the construction. The *di pan tu* defined the location and proportion of the buildings,⁹ and then the other forms of drawings were developed based on the *di pan tu*. The basic proportions between buildings are fixed and the volume of the building on the picture plane is depicted as it grows and occupies the space of the picture plane.

The other usage of the term of *di pan* gives a direct indication of its association with the spatial concept of cosmology. It refers to one of the two parts of an astronomical device – ‘*shi*’: the square ‘*di pan*’ symbolizing earth (Harper 1978, 1980; Li 2001; H. Wu 2007). The other part is the round ‘*tian pan*’ symbolizing heaven. The illustration patterns on *shi* are the most basic and formal geometrical cosmography (Henderson 1991), corresponding to the

spatial concepts of cosmology, which embrace the five basic patterns of cosmology: *si fang* (四方, four directions), *wu wei* (五位, five positions), *ba fang* (八方, eight points), *jiu gong* (九宮, nine palaces), and *shier du* (十二度, twelve divisions). The cosmography on *shi* strongly shaped all the expressions of *tu* expressing the philosophy of cosmology.

Although this device emerged in the Han period (202-220 BCE) and most of those found by archaeologists belong to Han (Li 2001), the use of the terms *di pan* and *tian pan* to refer to the two parts of the device did not occur in extant Han texts until they were used in various divination texts in the Tang Dynasty (Harper 1980). Numerous texts including *di pan*, whether to refer to the cosmological device or the other means, emerged around the Tang Dynasty. This situation once again demonstrates the differentiation that occurred around the time of the Tang Dynasty.

In conclusion, *di pan* is the direct inheritance and reinforcement of connotations of the early informative *tu* in the differentiation of the terminologies and types of drawing around the Tang and Song Dynasties. Considering the evidence above, the first evidence is that *di pan* refers to the representation of the plan of the building, as in the early informative *tu*; the second is that both the terminology of *di pan* and its geometrical composition embrace the concept of cosmology, like the early informative *tu*; and the last is that *di pan* functioned as the foundation of other *tu* after the differentiation.

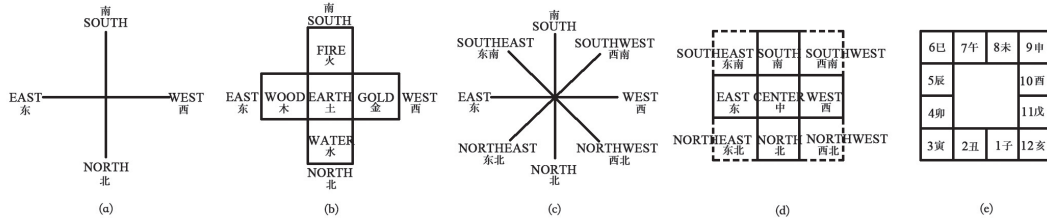


Figure 4: Spatial Concepts of Chinese Cosmology (Han Dynasty): (a) *si fang* (四方, four directions), (b) *wu wei* (五位, five positions), (c) *ba fang* (八方, eight points), (d) *jiu gong* (九宫, nine palaces), and (e) *shier du* (十二度, twelve divisions). (Illustration is drawn based on image in H. Wu 2007, 207).

1.2. SHI AND YANG: THE CONNOTATION OF COSMOLOGY AND MODEL.

While *di pan* inherits the connotation of *tu*, the terms *shi* and *yang* represent a new meaning—‘rule’ or ‘model’—which did not exist in the early *tu* period. This section investigates what is indicated by the emergence of *shi* and *yang*. Is there any difference between the meanings of *shi* and *yang*? If there is, what is indicated in this difference?

These two terms are easily assumed to have the same meaning, and the difference between ‘rule’ and ‘model’ are easily neglected. The denotation of *shi* includes both ‘rule’ and ‘model’ in the dictionary, indicating that *shi* can sometimes be the substitution of *yang*. Moreover, the collaborative and interchanged usage of these two terms in the texts strengthens their synonymous nature. The Qing scholar Duan Yucai, in his illustration for *Shuo Wen Jie Zi*⁷¹⁰ according to the Northern Song scholar Xu Xuan’s recension of this work in 986 CE, mentioned that “*Yang* now has the same connotation of a rule, model or pattern as *shi*.”¹¹

However, *shi* and *yang* have different mechanisms in developing the meanings of ‘rule’ and ‘model’ respectively. The term *shi* has two ways of accommodating the meaning of ‘rule’. One is the denotation of ‘rule, standard and law’ in the dictionaries, *Shuo Wen Jie Zi* and *Kang Xi Zi Dian*,¹² and has been used in texts since the Zhou (r. 1049/45-256 BCE) and Han (202-220 BCE) dynasties. It is often used together with *fa* (法, law) in this meaning:¹³ for instance, “*Using nine shi (rules) to manage the expenses*” in the *Zhou Li*¹⁴ compiled in the Warring States period (475-221 BCE), and “*Institutions and provinces have been precisely founded, and morals and rules have been thoroughly established*”¹⁵ in *Han Shu*,¹⁶ edited in the Eastern Han period (25-220 CE). Considering that the purpose of editing the book *Ying Zao Fa Shi* was to set the standard for financial evaluation of material and labor, *shi* in the book title means ‘rule’.

Shi’s second way of accommodating the meaning of ‘rule’ comes from the connotation indicated by the aforementioned astronomical device named *shi*. This astronomical device denotes the acknowledgement of the philosophy of cosmology. In this meaning, *shi* is often written using the character 式. For this reason, scholars who conduct research on cosmology, such as Harper, have claimed that these two meanings are totally separate (Harper 1980). However, considering the wide influence of cosmology in Chinese culture, which Needham called “correlative thinking” (Needham and Wang 1956), the two meanings have connotative interrelations. The meaning ‘rule, standard, and law’ represented by *shi* at the first level is in the domain of political institutions, or of ritual and moral standardization. These rules are made and executed in China under significant influence from the philosophy of cosmology (Henderson 1991; Smith 2013).

In contrast, *yang* has a different indication of the meaning ‘model’, which comes from the concept of intimation. This statement can be seen in the path of developing the meaning of *yang*. *Yang*’s (樣) original meaning is the fruit or seed of the *Xu* (栩) plant,¹⁷ documented in *Shuo Wen Jie Zi*, which was written in the Eastern Han Dynasty (25-220 CE). As the fruit of *Xu*, *yang* is also written as *xiang* (橡). *Xiang* has the meaning of similarity and imitation, from the character’s root meaning of *xiang* (象) and is represented as a model or pattern for others who share similarity and imitation. *Yang* borrowed this meaning from its variant character *xiang* (橡).¹⁸

When architectural terminologies adopt the two terms, the different mechanisms indicate their different connotations. The meaning ‘rule, standard, and law’ in the term *shi* is the institutional, moral and ritual rule under the influence of cosmology. It occupies an indirect position. Meanwhile, the meaning of ‘model’ in the term *yang*, which came from the concept of imitation, emphasizes the elegance and standardization

of an intellectual work that directs other works and can be imitated by others. For example, in *Tang Shu · Liu Gongquan Zhuan*, “the calligraphy of Liu Gongquan was so famous and widely imitated that it was called the Liu Model.”¹⁹ Moreover, the variant usage of the character *yang*, written as ‘掣’ instead of ‘樣’, in the Tang Dynasty reveals this indication as well. The left part ‘扌’ of the character ‘掣’ indicates that the ‘model’ represented by the character is hand-made and human-related. It emphasizes the intellectual work of a model rather than the original source of the character related to the wood indicated in the left part ‘木’ of the character ‘樣’.

The terminologies as one of the expressions of drawing show that architectural drawing becomes complicated in a different way from western drawings. The differentiation between *di pan* and *yang* is not like the difference between and among plans, elevations, and sections based on the different perspectives of view. Rather, the critical differentiation is that *di pan* shows that buildings should be arranged, and drawings should be composed under the influence of cosmology, while *shi* and *yang* develop the new concept of the model of an intellectual work. The difference between *shi* and *yang* still indicates that the indirect intention behind the model is still the philosophy of cosmology.

2. THE PICTORIAL DEVELOPMENT OF ARCHITECTURAL GEOMETRY

Corresponding to the development and differentiation of the sub-terminology of *di pan* and *yang*, the geometry of drawing has evolved as well. The previous section explained that the geometry of *di pan* inherited and complicated the simple cosmological geometry in the early *tu*. However, *yang* drawing embraced much more complex geometrical characters, which involved not just the complexity of the cosmological geometry as *di pan*. To some extent, there are some similarities between *li yang* (or *zheng yang*) and elevation, and between *ce yang* and section, according to the perspective of Euclidean projection by seeing through the picture plane (Pérez-Gómez and Pelletier 2000). This is also the reason why many researchers of Chinese drawing tend to categorize and align *di pan*, *li yang* and *ce yang* with the three views of plan, elevation and section in the Western Euclidean geometrical system.

This section uses a piece of *li yang tu* (Figure 5) from the *Yang Shi Lei tu* archives, which is now documented in the Forbidden City museum, to reveal the development of the architectural geometry in *yang tu*, and to investigate the difference between Chinese geometry and Euclidean geometry.

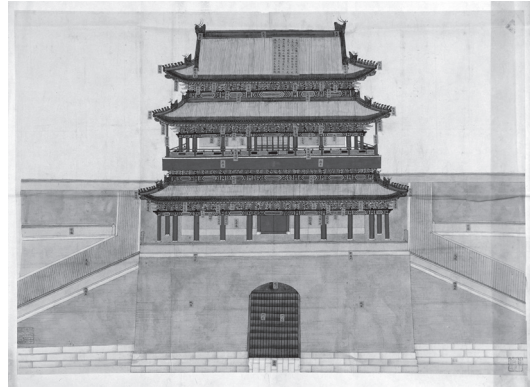


Figure 5: *Li Yang* of Zheng Yang Gate (© The Forbidden City Museum). (The National Library of China etc 2004)

2.1. THE ARCHITECTURAL TRANSFORMATION OF GEOMETRICAL COSMOLOGY: CENTRAL AXIS AND SYMMETRY

This *li yang* of the Zheng Yang Gate has developed complicated geometry and multiply composition layers through the arrangement of lines and duplication of components. The lines in *li yang tu* are arranged according to their positions and the relationships between and among them in the picture plane. The picture plane of the *li yang* is set up parallel with the frontal façade of the building. The lines of the objects parallel to the picture plane are drawn at right angles, as in the early informative *tu* (or like an orthogonal projection for easy acknowledgment), but the lines of the objects perpendicular to the picture plane are depicted in an oblique line. The direction of the oblique lines depends on the position of the lines against the central line of the picture plane, and all tilt toward the central axis; in other words, the left perpendicular lines tilt to the right side, and the right lines, which are symmetrical with the left ones, tilt in the opposite direction at the same angle. In addition, the perpendicular lines in the lower half tilt upwards and those in the upper half tilt downwards. A simple drawing in figure 6 clearly reveals those rules of the line's arrangement.

Some similarities and differences are clearly revealed between the geometry of the *li yang* and the western Euclidean geometry in elevation. If only lines parallel with the picture plane were drawn in the *li yang*, it would be more like the orthogonal elevation. Considering the relationship between the lines that are parallel with the picture plane and those that are perpendicular to it, there is a convergent tendency in *li yang tu*, as in the linear perspective. However, in the Chinese *li yang*, there are multiple centers rather than the single convergent point. When the oblique lines of

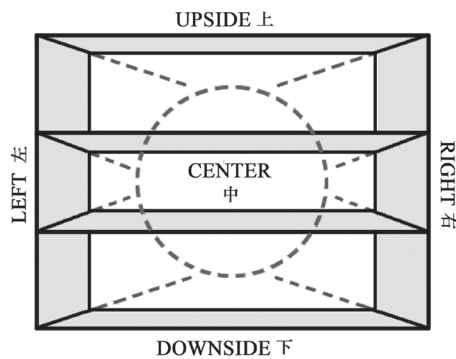


Figure 6: Illustration of the arrangement of the lines (Author 2019)

the part of the drawing on the left or the right side are drawn in the parallel tendency, this makes the quarter of the drawing similar to the composition in axonometric drawing. However, the fact that not all the oblique lines tilt at the exact same angle draws the composition away from axonometric projection. Wu Cong discussed Forseth projection, which is more like Chinese projection than linear perspective and axonometric projection (C. Wu 2004). But the critical difference is still that the lines in *li yang* are not strictly self-disciplined, as in any western scientific geometrical projection.

The arrangement of the lines, therefore, creates a unique hierarchical and relatively subjective geometry in the composition of the *li yang*, rather than the rigid and objective rules of projective Euclidean geometry. The system of Chinese geometry accommodates three levels of geometric language: the central axis and the axisymmetric rule; the four positions of left, right, upper and lower; and the multiple convergence centers constrained on the axis. The highest rank of the geometric language is the central axis and the axisymmetric rule. The components separated by the central axis are obliged to be drawn in symmetry along the central axis. Then, the tendency of the lines upwards and downwards, together with the compulsive symmetry of left and right, shapes the four positions. The multiple convergent centers are correspondingly produced rigidly on the central axis, but are rather flexible in their location in terms of upper and lower. These are the primary and dominant rules, preceding all other rules in the composition of the whole drawing. The other geometric aspects, such as the angle of the oblique lines and the separation between the upward and downward tendencies of the oblique lines, are relatively flexible.

Although the typical composition of geometrical cosmography, as in the idealized city plan, the Luminous Hall, and the illustrations on the device *shi*, is hardly

legibly seen in the pictorial *li yang tu*, the four positions of upper, lower, left and right are still clearly indicated in the composition of the geometry by the tendency of those tilted lines. The position of the middle area—indicated by the tendency of the multiple convergent centers compared to the single center of the western linear perspective—furthermore highlights that spatial characters indicated in the drawing correspond to the cosmological concepts of the four directions and five positions. The middle area in the concept of five positions in Chinese cosmology is not one central point, but rather an area similar to the other four positions, and even more dominant than these other positions. Evans, in his article, argued that the development of centers in the central church is associated with the important cultural meaning of centers to western cosmology and the projection of centers into religious central cathedrals (Evans 2000). In Chinese cosmology, five positions with a dominant central position are valued, and therefore projected into such geometry in *tu*, but not the concept of the singular center (Pérez-Gómez and Pelletier 2000), as in western cosmology.

Meanwhile, the rigid spatial characters of the central axis and symmetry are the solid concentration on architectural characters in drawing languages. Ever since the birth of Chinese buildings, whether single buildings or combinations, the axis and symmetry are the basic characters that have remained consistent throughout, from the earliest archaeological findings of building combinations, such as the Xi'an Banpo Hemudu Ruins, to the Forbidden City and many mausoleum sites in the Qing Dynasty; from the building model documented in the Ming Qi funerary ware in the Warring States period and the Han Dynasty to Taihe Dian in the Forbidden City. Because of the correlative influence of cosmology on buildings, these characters are absolute, under the embrace of cosmology; however, compared to other regions and the basic and typical geometrical cosmography, axis and symmetry were already developed as architectural characteristics. The geometric languages in *li yang* that demonstrate these two spatial characters in a rigid way take precedence over other geometric languages, which are relatively flexible. The *yang* drawing, therefore, developed the architecturalizing character, rather than being subject to the composition of basic geometrical cosmography.

2.2. THE PICTORIAL ENDORSEMENT OF ARCHITECTURAL GEOMETRY

The obliqueness of the perpendicular lines creates an illusion of depth in the picture plane. This illusion is created not only by the convergent tendency of perpendicular lines in axisymmetric objects, but also by the way in which the components are depicted. The



Figure 7: Part of Figure 5, *Li Yang* of Zheng Yang Gate (© The Forbidden City Museum). (The National Library of China etc 2004).

latter are depicted in the form of a 'three-quarter profile' which contains, not only the frontal side, but also part of the lateral side of the object. In the sets of brackets in the *li yang* (Figure 7), for instance, each set is depicted with the parallel plane together with part of the oblique perpendicular plane, as in this kind of 'three-quarter profile' (or like the axonometric projection in Euclidean geometry).

This way of depicting *li yang* adopted a conventional Chinese method of composing pictorial 3D objects into a 2D picture plane. This conventional method has dominated the Chinese pictorial traditions from the very beginning, whether in depictions of living creatures or of objects. The separate brackets and other components in the *Ying Zao Fa Shi* are illustrated in the exact same way. This is the most common way to depict a single object in the illustration plates in Chinese books.

However, although the oblique lateral part of the drawing gives a hint of depth for the objects, this style is still a flattened way of describing human figures, animals, and objects, rather than creating spatial depth, as in the Euclidean geometry. George Rowley interpreted this style as an "ideational" style. He pointed out that the Chinese representation of the mind dealt with the ideas in their essential results in the ideographic image of the thing, rather than providing a descriptive likeness in pre-Tang painting. Objects following this logic were depicted in a flat profile or *en face* mode (Rowley 1960). Wu Hung approved Rowley's conclusion as the best description and interpretation, although there were numerous archaeological findings after Rowley's book (H. Wu 1989). In early pictorial art, this kind of combination of objects on a two-dimensional picture plane without emphasizing spatial depth is very common, such as the images on the Bronzeware in the Warring States period and the images on the ceiling and walls of the Wu Liang Shrine. Wu Hung used the term "cataloguing style" to describe the arrangement of the objects depicted in flat style in his research on the Wu Liang Shrine. The individual units depicted in flat style are organized separately, as in a catalogue, in the early Han pictorial art (H. Wu 1989).

This thesis will call this style a 'three-quarter profile' because the objects in this style of architectural *tu* inherits not only the pictorial convention but, more importantly, the additional 'quarter' of the object embraces an additional indication, in contrast to

depicting merely the frontal side of the object. The appearance of the additional 'quarter', in which direction and on which side, is subject to the dominant geometrical rules and therefore intensifies these rules to the viewers. The 'three-quarter profile' way of depicting objects fosters greater meanings that are valuable in Chinese drawing than does the flat frontal view.

Li yang evolved from the early *tu*, which still embraced the cosmological concepts of four directions and five positions. However, it developed dominant architectural characters on the picture plane by following the rigid architectural transformations and geometrical rules of central axis and symmetry. It transformed to become a pictorial *tu* by completing the basic pictorial components in three-four quarter profile traditions. However, in contrast with painting and in keeping with the heritage of cosmological *tu*, it arranged the pictorial components in a "cataloguing style" under the dominant architectural geometry. From then on, *yang tu* was established as architectural drawing, entangled both with the *tu* tradition and the pictorial tradition.

CONCLUSION

From the consideration of the development of the etymology of the terminologies and the geometry in the picture plane, a clear picture emerges of the evolution that occurred around the Tang and Song Dynasty and matured later in history. The terms etymologically accommodate both the connotation from the philosophy of cosmology and the meaning of 'model' as the new ideal of intellectual work. The geometry of drawing, entangled with cosmography and painting traditions, established drawing in this stage as a unique architectural drawing, neither as technical *tu*, nor as painting.

The evolution of *tu* reveals the start of the development of architectural preferences in and around the Tang and Song Dynasties and evokes the unchanging cultural intentions under the influence of the philosophy of cosmology. Moreover, research indicates that architectural drawings are still a form of collective intellectual work, and not constitutive of any individual subjectivity. This is one of the main differences between ancient *tu* and modern architectural drawings. This article provides a foundation for understanding the modernization of Chinese architectural drawing.

ENDNOTES

- 1 In this article, the Chinese characters in terms of the terminologies of *tu* and ancient texts are written in traditional characters instead of simplified version. The characters in references by modern researchers are still in simplified Chinese.
- 2 I use the connotation of geometry in a broad concept. Here, when it refers to the geometry in Chinese drawing, I mean how the lines (and sometimes together with the text) in the picture plane are arranged and organized to form the whole object.
- 3 *The Builder* and *The Chinese Architecture* were two professional journals published in 1930s.
- 4 *Zhaoyu tu* is a simply illustrated drawing on a bronze plate excavated the Zhong Shan necropolis during the Warring States period (B.C.475- B.C.221).
- 5 The classical city plan was firstly documented in the "Record of Trades" section of the Rituals of Zhou. One passage is described as follow: "The master craftsman constructs the state capital. He makes a square nine li on each side; each side has three gates. Within the capital are nine north-south and nine east-west streets. The north-south streets are nine carriage tracks in width." ("方九里，旁三门，國中九經九緯，經塗九軌"). The English version of text comes from (Steinhardt 2002) P24.
- 6 Archaeology finding show that *Zhaoyu tu* are drawn to scale, see in (Yang 1980). Research revealed its relationship with the philosophy of cosmology, see in (H. Wu 2007).
- 7 The original text in Chinese is "諸葛地自立后，遣使可倫因地盤獻火珠，狀如水精，.....云得之于羅刹國" documented in the Chapter *Lin Yi* (《林邑》) in the volume *Bian Fang Si* (《边防四》) in the book *Tong Dian* (《通典》).
- 8 The original text in Chinese is "识得道理原头，便是地盘。如人要起屋，须是先筑教基址坚牢，上面方可架屋" documented in the book *Zhu Zi Yu Lei* (《朱子语类》).
- 9 The *di pan tu* in Yang Shi Lei tu archive is drawn to scale. See in (Wang 2016)
- 10 *Shuo Wen Jie Zi* is the earliest Chinese dictionary edited by Xu Shen in Eastern Han Dynasty (25-220).
- 11 The original text in Chinese is "今人用樣為式樣字。像之假借也。唐人式樣字從手作樣。" Reference is searched in the *Han Dian* database: <https://www.zdic.net/hans/樣>.
- 12 *Kang Xi Zi Dian* is a dictionary edited by the court in the Qing dynasty (1636-1912), which gathered together the varieties of ancient meanings of thousands of Chinese characters and the original texts where these meanings were shown.
- 13 (Cullen 1980)
- 14 The original text in Chinese is "以九式均節財用." documented in the Chapter *Da Zai* (《大宰》) in the volume *Tian Guan* (《天官》) in the book *Zhou Li* (《周禮》).
- 15 The original text in Chinese is "樞機周密，品式備具." documented in the volume *Xuan Di Ji* (《宣帝紀》) in the book *Han Shu* (《漢書》)
- 16 *Han Shu* is the first historical text edited in series of biographies, edited by Ban Gu in the Eastern Han Dynasty.
- 17 *Xu* is a species in the family of *Xylosma racemosum* (Sieb. et Zucc.) Miq. in Latin. Reference is searched in the *Han Dian* database: <https://www.zdic.net/hans/樣>.
- 18 The Qing scholar Duan Yucui in his illustration for *Shuo Wen Jie Zi* according to the Northern Song scholar Xu Xuan's recension of it in 986, mentioned "Yang now has the same connotation of a rule, model or pattern with *shi*, borrowing the meaning from the character of *xiang* (像)." However, he did not mention the difference between the two. The original text in Chinese is "今人用樣為式樣字。像之假借也。唐人式樣字從手作樣。" Reference is searched in the *Han Dian* database: <https://www.zdic.net/hans/樣>.
- 19 The original text in Chinese is "公權在元和間書法有名，劉禹錫稱為柳家新樣", documented in the Chapter *Liu Gong Quan Zhuan* (《柳公權傳》) in the book *Tang Shu* (《唐書》).

REFERENCES

- Barnhart, Richard M, James Cahill, Chongzheng Nie, Shaojun Lang, Hung Wu, and Xin Yang. 1997. *Three Thousand Years of Chinese Painting*. New Haven: Yale University Press.
- Behr, Wolfgang. 2007. "Placed into the Right Position—Etymological Notes on Tu and Congeners." In *Graphics and Text in the Production of Technical Knowledge in China*, 109-134. Leiden · Boston: Brill.
- Bray, Francesca, Vera Dorofeeva-Lichtmann, and Georges Métaillie. 2007. *Graphics and Text in the Production of Technical Knowledge in China: the Warp and the Weft*. Leiden · Boston: Brill.
- Chung, Anita. 2004. *Drawing Boundaries: Architectural Images in Qing China*. Honolulu: University of Hawaii Press.
- Cullen, Christopher. 1980. "Some Further Points on the "Shih". *Early China* 6: 31-46.
- Evans, Robin. 2000. *The Projective Cast: Architecture and its Three Geometries*. Boston: MIT press.
- Forseth, Kevin. 1984. *Glide Projection: Lateral Architectural Drawing*. London: Van Nostrand Reinhold Company.
- Golas, Peter J. 2014. *Picturing Technology in China: From Earliest Times to the Nineteenth Century*. Hong Kong: Hong Kong University Press.
- Harper, Donald J. 1978. "The Han Cosmic Board (Shih). *Early China* 4: 1-10.

Terminology and Geometry

- Harper, Donald J. 1980. "The Han Cosmic Board: A Response to Christopher Cullen." *Early China* 6: 47-56.
- He, Beijie, and Zhen Shi. 2013. "Textual Research on Lei's Family Tree (Yang Shi Lei Shi Jia Zu Pu Kao Lue)." *Cultural Relics* (Wen Wu) 4: 74-80.
- Henderson, John B. 1984. *The Development and Decline of Chinese Cosmology*. New York: Columbia University Press.
- Li, Ling. 2001. *Research on Chinese Fangshu* (Zhong Guo Fang Shu Kao). Beijing: Oriental Publishing House (Dong Fang Chu Ban She).
- Liu, Keming. 2006. *Chinese Architectural Drawing Cultrues* (Zhong Guo Jian Zhu Tu Xue Wen Hua Yuan Liu). Wuhan: Hubei Education Press (Hu Bei Jiao Yu Chu Ban She).
- Needham, Joseph, and Ling Wang. 1956. *Science and Civilization in China: Mathematics and the Sciences of the Heavens and Earth*. Vol. 3. Cambridge: Cambridge University Press.
- Ota, Shoichi. 2005. "Chinese Architectural and Construction Drawings from the Qing Dynasty." In *The Collection of the Institute of Oriental Culture at the University of Tokyo*, edited by Naomi Inoue. Tokyo: Institute for Advanced Studies on Asia.
- Pérez-Gómez, Alberto and Louise Pelletier. 2000. *Architectural Representation and the Perspective Hinge*. Boston: MIT Press.
- Rowley, George. 1960. *Principles of Chinese Painting*. Princeton: Princeton University Press.
- Smith, Richard J. 2013. *Mapping China and Managing the World: Culture, Cartography and Cosmology in Late Imperial Times*. Abingdon: Routledge.
- Steinhardt, Nancy, ed. 2002. *Chinese Architecture*. New Haven: Yale University Press.
- The National Library of China, ed. 2016. *Yang Shi Lei Tu Archives: Yuan Ming Yuan I* (Guo Jia Tu Shu Guan Cang Yang Shi Lei Tu Dang: Yuan Ming Yuan Juan Chu Bian). Beijing: National Library of China Publishing House (Guo Jia Tu Shu Guan Chu Ban She).
- The National Library of China, ed. 2017. *Yang Shi Lei Tu Archives: Yuan Ming Yuan II* (Guo Jia Tu Shu Guan Cang Yang Shi Lei Tu Dang: Yuan Ming Yuan Juan Xu Bian). Beijing: National Library of China Publishing House (Guo Jia Tu Shu Guan Chu Ban She).
- The National Library of China, ed. 2018. *Yang Shi Lei Tu Archives: Yi He Yuan* (Guo Jia Tu Shu Guan Cang Yang Shi Lei Tu Dang: Yi He Yuan Juan). Beijing: National Library of China Publishing House (Guo Jia Tu Shu Guan Chu Ban She).
- The National Library of China, ed. 2004. *Masterpieces of Architectural Conceptions of Ancient China: Exhibition of Yangshi Lei Architectural Archives of the Qing Dynasty* (Hua Xia Jian Zhu Yi Jiang De Chuan Shi Jue Xiang: Qing Dai Yang Shi Lei Jian Zhu Tu Dang Zhan).
- Wang, Qiheng. 2014. "Construction Order and Etiquette of the Mausoleum Project in the Qing Dynasty (Qing Dai Ling Qin Gong Cheng De Shi Gong Ci Xu He Li Yi)." In *Ten Books of Contemporary Chinese Architectural Historians: Wang Qiheng's Selection Works on Chinese Architectural History* (Dang Dai Zhong Guo Jian Zhu Shi Jia Shi Shu: Wang Qi Heng Zhong Guo Jian Zhu Shi Lun Xuan Ji). Shenyang: Liaoning Fine Art Publishing House (Liao Ning Mei Shu Chu Ban She): 80-89.
- Wang, Qiheng. 2016. "A Study of Pingge Drawings from the Yangshilei Archives: Architectural Design Concept and Method in the Qing Dynasty of China" (Qing Dai Yang Shi Lei Jian Zhu Tu Dang Zhong De Ping Ge Yan Jiu: Zhong Guo Chuan Tong Jian Zhu She Ji Li Nian Yu Fang Fa De Jing Dian Fan Li). *Heritage Architecture* (Jian Zhu Yi Chan) 1: 24-33.
- Wang, Qiheng, and Fengwu Zhang. 2009. "The Conclusion of the Drawing Time of the Yuanming Yuan Plan of Yangshi Lei (Yi Fu Yang Shi Lei Yuan Ming Yuan Quan Tu De Nian Dai Tui Duan)." *Chinese Landscape Architecture* (Zhong Guo Yuan Lin) 6: 83-87.
- Wang, Qiheng, and Long Zhang. 2008. "The Restoration and Reconstruction of the Summer Palace during Guangxu Period and Yangshi Lei Archives (Guang Xu Chao Yi He Yuan Chong Xiu Yu Yang Shi Lei Tu Dang)." *Chinese Landscape Architecture* (Zhong Guo Yuan Lin) 6: 23-31.
- Wu, Cong. 2004. *Beyond Projection: Architectural Drawing in Cultural Perspectives* (Zai Tou Ying Zhi Wai: Wen Hua Shi Ye Xia De Jian Zhu Tu Xue Yan Jiu). Tianjin: Tianjin University Press (Tian Jin Da Xue Chu Ban She).
- Wu, Hung. 1989. *The Wu Liang Shrine: The Ideology of Early Chinese Pictorial Art*. Stanford: Stanford University Press.
- Wu, Hung. 2007. "Picturing or Diagramming the Universe." In *Graphics and Text in the Production of Technical Knowledge in China: The Warp and the Weft*, edited by Francesca Bray, Vera Dorofeeva-Lichtmann, and Georges Métaillie. Leiden · Boston: Brill: 191-214.
- Wu, Jiming. 1988. *Chinese Drawing History* (Zhong Guo Tu Xue Shi). Wuhan: Huazhong University of Technology Press (Hua Zhong Li Gong Da Xue Chu Ban She).
- Yang, Hongxun. 1980. "Study of the King's Mausoleum of Warring State's Zhongshan Kingdom and Zhaoyu Tu (Zhan Guo Zhong Shan Wang Ling Ji Zhao Yu Tu Yan Jiu)." *Acta Archaeologica Sinica* (Kao Gu Xue Bao) 1: 119-138.
- Yang, Hongxun. 1987. *Yang Hongxun Selection Works on Architectural Archaeology* (Yang Hong Xun Jian Zhu Kao Gu Xue Lun Wen Ji). Beijing: Cultural Relics Publishing House (Wen Wu Chu Ban She).
- Zou, Hui. 2011. "Perspective Jing: The Depth Architectural Representation in a European-Chinese Garden Encounter." In *Chora, Volume Six, In Intervals in the Philosophy of Architecture*, 275-304. Montreal: McGill-Queen's University Press.

OPERABLE WINDOWS, THERMAL COMFORT, AND INDOOR AIR QUALITY IN K-12 SCHOOLS: Identifying the Gap and Proposing Future Studies

Helia Taheri
Traci Rose Rider
North Carolina State University

Abstract: Schools are the second most important environment in children's lives after homes (Baki-Biro et al. 2012; Mendell et al. 2013), illustrating the importance of school environments in students' learning performance, health, and comfort (Abramson et al. 2006; Madueira et al. 2009; Annesi-Maesano et al. 2013; Mendes et al. 2014; Almeida et al. 2016). Ventilation is one of the factors impacting student learning performance; ventilation can be provided through operable windows, exhaust fans, or mechanical ventilation systems (Gao et al. 2014). Additionally, different building elements such as air ventilation systems, HVAC systems, and building envelopes, can affect ventilation and occupant comfort (Catalina and Iordache 2012). ASHRAE Guideline 10P (2010) establishes four conditions for human comfort: thermal, visual, acoustic, and indoor air quality. Thermal comfort and indoor air quality are viewed as the most important of the four comfort conditions to improve occupant health and productivity (Pan et al. 2018). Several studies have focused on the relationship between operable windows, thermal comfort and/or indoor air quality, but no literature is found synthesizing these studies to establish a gap in research (Almeida et al. 2016; Dhaka et al. 2013; Jiang et al. 2018; Jindal 2018).

Through searching such keywords as operable windows, natural ventilation, open window, close window, temperature, thermal comfort, CO₂, indoor air quality, and IAQ, 136 articles were found on Web of Science, ScienceDirect, and Google Scholars. From these papers, only thirty-one had research conducted in schools. A synthesis shows that these thirty-one articles have been conducted largely through quantitative methods, including environmental monitoring, survey, and simulation. Also, only one of them was located in the U.S., with the rest located in Europe (15 out of 31), Asia (12 out of 31), South America (2 out of 31) and South Africa (2 out of 31). In addition, 54% of the total (thirty-one) papers focused only on thermal comfort, 25% focused on indoor air quality and only 21% addressed the relationship between operable windows and both thermal comfort and indoor air quality in K-12 classrooms. This synthesis of literature shows that the current research emphasized measurements in air temperature, relative humidity, and air velocity to address thermal comfort, and used CO₂ as the favored metric for measuring indoor air quality. This paper proposes future studies and methodologies to fill these identified gaps in the literature.

Keywords: Operable windows, thermal comfort, indoor air quality, K-12 schools, classroom

INTRODUCTION

Schools are historically important environments for communities, design professionals, and the general public for two primary reasons. First, schools often have environmental deficiencies due to funding shortages related to operation and facility maintenance (U.S. General Accounting Office 1995; Mendell et al. 2013). Second, classrooms are the second most important spaces for children, trailing only the home environment (Baki-Biro et al. 2012; Mendell et al. 2013). With students spending approximately one-third of their waking time at school, the importance of school environments on student health, well-being, and comfort is apparent (Abramson et al. 2006; Madueira et al. 2009; Annesi-Maesano et al. 2013; Mendes et al. 2014; Almeida et al. 2016). These impactful spaces represent a micro-environment for a vulnerable childhood population as they are still physically and mentally developing (Stabile et al. 2017; Peled 2011; Selgrade et al. 2008). Children

are more vulnerable to environmental conditions, particularly pollutants (Suk et al. 2003); they breathe higher volumes of air relative to their weight, exposing them more to toxins compared to adults (Suk et al. 2003). In designing classrooms and schools, architects generally try to ensure that the environment improves student learning, performance and comfort. While these elements should be the priority in a school design, the literature shows that the energy analysis and cost effectiveness are also important in decision making processes (Catalina and Iordache 2012).

Ventilation may be a significant factor helping to improve students' learning performance and reducing the risk of health problems, (Gao et al. 2014). Inadequate ventilation can cause an increase in absenteeism, which has shown a negative consequence of impacting learning (Mendell et al. 2013). The literature shows that the current ventilation rates in classrooms are still

inadequate and lower than in office and residential buildings (Daisey and Angel 2003; Santamouris et al. 2008; Gao et al. 2014). Some actions have been proposed for existing and future schools to increase classrooms indoor environment quality, such as: (i) adequate outdoor ventilation, (ii) control of moisture, and (iii) avoiding indoor exposures to pollutants (Bako-Biro et al. 2012). There are many ways to provide increased classroom ventilation including operable windows, exhaust fans, or mechanical ventilation systems. There is not a systematic data analysis on the impact of these different ventilation types on students' and teachers' comfort and health, or on student learning level in classrooms (Gao et al. 2014). Several elements, such as HVAC systems, building envelopes, occupant behavior, and air ventilation systems influence indoor environmental conditions (Catalina and Iordache 2012). Comfort has been studied in terms of four conditions: thermal (air velocity, temperature and humidity), visual (illuminance and reflection), indoor air quality (smells, irritants, outdoor air, and ventilation), and acoustics (control of unwanted noise, vibrations, and reverberations) (Ortiz et al. 2017; Bluysen 2009). Thermal comfort and indoor air quality are two important comfort conditions that can improve both occupant's health and productivity (Pan et al. 2018). Since thermal discomfort may have a negative influence on students' learning performance, and classrooms have high densities compared to office spaces or residential buildings, providing appropriate comfort conditions in educational buildings has always been important and critical (Mendell and Heath 2005; Barrett et al. 2015).

Thermal comfort is "that condition of mind which expresses satisfaction with the thermal environment and is assessed by subjective evaluation" (ANSI/ASHRAE Standard 55 2013). Individuals may feel differently in the same thermal condition, or different people may have the same levels of comfort in different thermal environments (ANSI/ASHRAE Standard 55 2017). Two models are commonly used internationally to discuss thermal comfort: (i) the "rational" model, and (ii) the "adaptive" model (Martinez-Molina et al. 2017). The "rational" model is the work of Fanger, who established the Predicted Mean Vote (PMV) and Predicted Percentage of Dissatisfied (PPD). PMV is an index that predicts the votes of a large group on a 7-point thermal sensation scale, and PPD is an index that predicts the percentage of people who experience local discomfort (Fanger 1970). The main principle of the "adaptive" model focuses on human-building interaction, where people can improve their environment by interacting with both building controls (opening/closing windows/doors and turning on/off fans), and with

personal conditions (changing their clothes or drinking hot or cold drinks). This model is the most realistic model for naturally ventilated buildings (Stazi et al. 2017).

Indoor air quality is also an important parameter for school environments, since it is related directly to occupants' health and comfort, indoor air quality should not be neglected in indoor environmental quality studies (Catalina and Iordache 2012). The definition of acceptable indoor air quality in terms of occupant satisfaction is a room where no contaminants reach a harmful concentration level and at least 80% of occupants do not express any dissatisfaction about the air (Lai et al. 2009).

The effect of natural ventilation on thermal comfort and indoor air quality is not easily predictable; it is important to further investigate this strategy (Stabile et al. 2017). Ventilation types in buildings might vary from completely natural to completely mechanical and can be categorized into three groups: (i) natural, (ii) mechanical, and (iii) mixed or hybrid. Many studies have been conducted on mechanically ventilated classrooms, while there is a lack of knowledge and information addressing naturally ventilated schools (Almeida et al. 2016). In places with mild outdoor climates, opening windows can reduce indoor cooling demands, and enhance indoor air quality (Pan et al. 2018).

When the building utilizes natural ventilation, opening windows can provide the interior with cool and fresh air from outside (Rackes and Warning 2013). In Portugal, like other mild climate countries, schools prefer natural ventilation instead of mechanical ventilation (Almeida and de Freitas 2014; Almeida et al. 2016). In naturally ventilated schools where temperature fluctuation is higher, students' adaptability is required to maintain an appropriate level of comfort (Almeida et al. 2016). Among the studies specifically on natural ventilation in school buildings, no agreement has been reached on the ventilation required to improve indoor air quality and thermal comfort (Dorizas et al. 2015); therefore, more studies are needed to understand various factors in this field.

Wargocki et al. (2002) state that having ventilation systems, either natural or mechanical, can impact people's health in buildings, particularly during cold seasons. The study also mentions that students have lower frequency of complaints in naturally ventilated schools. Meanwhile, some drawbacks of naturally ventilated schools, such as outdoor noise, air quality, safety parameters should be considered (Santamouris et al. 2008). Several studies regarding natural ventilation in schools and the relationships between operable windows and human comfort, especially addressing thermal comfort and indoor air quality, will be discussed in the following sections.

The influence of the indoor environment on occupant comfort and productivity, and the growing awareness of these issues, has led to an increase of efforts to obtain feedback from users of buildings via survey (Catalina and Iordache 2012; Lai et al. 2009; Andersen et al. 2009). Due to the importance of natural ventilation in classrooms and of thermal comfort and indoor air quality in providing human comfort, and considering the lack of the systematic literature review on this subject, this study synthesizes the literature on the relationship between operable windows, thermal comfort and indoor air quality in K-12 classrooms.

METHODOLOGY

The Web of Science, Google Scholar, and ScienceDirect databases were used to search for literature on operable windows, thermal comfort, and indoor air quality. The keywords used were *operable window*, *natural ventilation*, *open windows*, *close window*, *temperature*, *thermal comfort*, *CO₂*, *indoor air quality*, and *IAQ*. One hundred and thirty-six (136) papers were found through the initial search, with only thirty-one (31) were conducted in schools. This paper synthesizes this literature based on the study locations, targeted concepts of the study, methods, and the parameters of the measurements. This synthesis helps to understand the gap in the literature to aid in building future studies in a more efficient way.

RESULTS

Findings from the studies will be discussed in three parts: (i) thermal comfort and operable windows, (ii) indoor air quality and operable windows, and (iii) thermal comfort, indoor air quality and operable windows. A synthesis of the three will then be provided.

Therman Comforty and Operable Windows:

Operable windows impact both temperature and air velocity (Brager et al. 2004). Kumar et al. (2016) conducted a study to update the thermal boundaries in the psychrometric chart for naturally ventilated buildings. They used survey and environmental monitoring. The resulting proposed thermal comfort boundaries from this study have higher range compare to ASHRAE comfort zone which shows that people in naturally ventilated buildings have more thermal tolerance range, Mishra and Ramgopal (2015) state that students in naturally ventilated classrooms in tropical climates implement adaptive behaviors to improve their thermal comfort such as using fans, opening/closing windows, and changing clothes. They used survey and environmental monitoring in their study. Ogoli (2007) studied thermal comfort in naturally ventilated school buildings in Chicago based on a previous study

of his done in Kenya, but since the sample of the Chicago study was very small, he indicated that it is a preparation for future studies in this field. They used survey and environmental monitoring in their study. Singh et al. (2018) studied thermal comfort during the summer season in naturally ventilated classrooms in composite climate in India, which is hot and dry, warm and humid as well as cold climate. They used survey and environmental monitoring. The results showed that there is a higher temperature fluctuation in naturally ventilated classrooms (79.9-96.8F) across different buildings. Also, around 80% of the participants responded to the thermal comfort question to be comfortable in the comfort band (+1 thermal sensation) in all naturally ventilated classrooms. In most of the literature about thermal comfort and operable windows, they showed that students in classrooms with operable windows have more tolerance about higher and lower temperatures and make them more adaptable to their environment.

Indoor Air Quality and Operable Windows:

Griffiths and Eftekhari (2008) conducted a study on ventilation performance of the naturally ventilated classroom in the UK and their relationship with CO₂ concentration. They used environmental monitoring. The study shows that a 10-minutes opening windows in the break time between classes can help decrease CO₂ concentration in the classrooms around 1000ppm without compromising thermal comfort. The study also finds that to keep the CO₂ concentration in an acceptable range, more than two periods of this type of ventilation will be required. Heudorf et al. (2009) conducted a study on the relationship between ventilation, CO₂, and particulate matter in classrooms in Germany. They used environmental monitoring to measure CO₂ levels in two mechanically ventilated classrooms, for three weeks; in the last week, a protocol was used to engage operable windows between classes to improve ventilation rates. The results showed that during that third week, the mean value of the CO₂ concentration was reduced to 1000ppm. The literature shows that although using natural ventilation alone is not efficient for improving indoor air quality, combining it with mechanical ventilation systems can improve indoor air quality in an acceptable range.

Thermal Comfort, Indoor Air Quality and Operable Windows:

De Giuli et al. (2012) conducted a study on the relationship between indoor environmental quality and student perception of comfort in Venice, Italy. They used survey and environmental monitoring. They found that in naturally ventilated spaces, closed windows are the

Operable Windows, Thermal Comfort, and Indoor Air Quality in K-12 Schools

main cause of students' dissatisfaction about indoor air quality during class time. Similarly, Dias Pereira et al. (2014) studied the relationship between thermal sensation, thermal comfort, and indoor air quality in naturally ventilated secondary schools in Portugal. They used survey and environmental monitoring. Results show that students felt comfortable in both higher and lower temperatures beyond the limits of the standard ASHRAE comfort zone. On the other hand, the CO₂ concentration in these natural ventilated classrooms exceeded the standard ASHARE limits. To further address the possible benefits of operable windows, Stazi et al. (2017) conducted a study for developing an automatic system for operable windows and evaluated the effect of the automatic system on thermal comfort and indoor air quality in the classroom in Italy. They used survey and environmental monitoring. Results indicate that the priority of students for opening/closing windows is their thermal comfort (such as indoor and outdoor temperature) and CO₂ concentration is not a tangible factor for them. In the designed automatic system, there will be sensors to sense the CO₂ level so it will take CO₂ concentration into account, so that CO₂ level is usually below 1500ppm and users were thermally comfortable.

Liu et al. (2019) conducted a study to understand the relationship between thermal comfort and perceived indoor air quality in naturally ventilated classrooms in China. They used survey and environmental monitoring. The results show that CO₂ concentration did not have any relationship with the rate of dissatisfaction with indoor air quality, which was higher than 20%. Survey results indicate occupant density in the classrooms did not have any impact on the perceived thermal comfort, while density did influence perceived indoor air quality. The results show that the factor having the highest effect on occupants' acceptability of indoor air quality is thermal sensation. The literature shows that thermal comfort is more tangible than indoor air quality for the users of operable windows, that is why when they feel hot/cold they open/close windows. But they never open/close windows when the CO₂ concentration is high because they cannot sense it. One of the solutions is having automatic operable windows which have a CO₂ sensor to measure the CO₂ level and alarm the user when it is the time for open/close the windows.

Synthesis of the Literature:

This literature review and synthesis shows that all the previous research was conducted by using quantitative methods including environmental monitoring, survey data, and simulation. Also, most of the studies were completed in Europe and Asia; only one study was conducted in the United States. Figure 2 shows the percentage of studies in different areas.

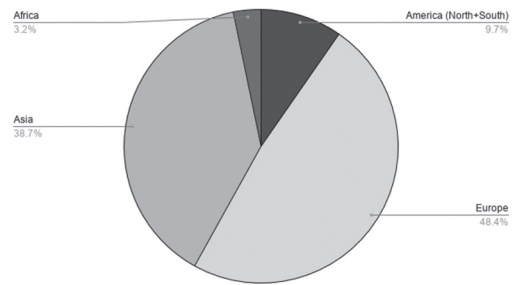


Figure 1: Percentage of studies in difference areas. (Author 2019)

Among the total of the thirty-one studies found, 54% (17 out of 31) focused only on thermal comfort and operable windows, 25% (8 out of 31) focused on indoor air quality and operable windows, and only 21% (6 out of 31) addressed operable windows and both thermal comfort and indoor air quality (Table 1). There is a gap in the location of the study and methodology of the research in this field.

To measure thermal comfort with environmental monitoring, all studies measured air temperature and relative humidity. Eleven of the studies also measured air velocity (table 1). For measuring indoor air quality, CO₂ levels were measured using indoor air quality sensors. In twenty-one of the thirty-one studies, survey was used to understand occupant thermal comfort and/or indoor air quality perceptions in classroom (table 1). All the twenty-one studies asked questions from students, despite the teachers having agency over the operable windows. The teachers' behaviors have not been addressed in these studies.

DISCUSSION

Schools are the second most important space in children's life after their home environment (Baki-Biro et al. 2012; Mendell et al. 2013), supporting the importance of the school environment in their health, well-being, and comfort (Abramson et al. 2006; Madueira et al. 2009; Annesi-Maesano et al. 2013; Mendes et al. 2014; Almeida et al. 2016). Children are more vulnerable to toxins as compared to adults, because they breathe in higher volumes of air relative to their weight (Suk et al. 2003).

When designing classrooms, improving student learning, performance, and comfort should be prioritized by architects (Catalina and Iodache 2012). Ventilation is one factor that can improve students learning performance and health in classrooms and schools (Gao et al. 2014). There are many ways to provide increased and appropriate ventilation, such as operable windows, exhaust fans, or mechanical ventilation systems (Gao et al. 2014). In many schools, ventilation is expected to be provided by teachers or students

Author	Year	Location	Thermal	IAQ	Yes/No	Survey	Yes/No	Sample	Temp	RH	ACH	CO ₂	VOC	Environmental Monitoring	Simulation
Madureira et al.	2016	Portugal		x	No		Yes	73 classes				x	x		
Heudorf et al.	2009	Germany		x	No		Yes					x			
Coley and Beisteiner	2002	UK		x	No		Yes	7 classes	x			x			
Giffith and Eftekhari	2008	UK		x	No		Yes					x			
Chithra and Nagendra	2012	India		x	No		Yes	1 school	x	x		x		COPMs	
Dorizas et al.	2015	Greece		x	Yes		Yes	9 schools			x	x	x	COPMs	
Fuoco et al.	2015	Italy		x	No		Yes	3 schools	x	x		x			
Krawczyk et al.	2016	Portland and Spain		x			Yes				x	x			
Almeida et al.	2016	Portugal	x		Yes	10 Schools	Yes	10 schools	x	x		x			
Buonocore et al.	2019	Brazil	x		Yes		Yes		x	x					
Djamilia	2017	Malaysia	x		Yes										x
Ge et al.	2019	Singapore	x		No		No								
Zhang et al.	2007	China	x		Yes	25 classes	Yes		x	x				Air Vel.	x
Huang and Hwang	2016	Taiwan	x		No		No								
Jinal	2018	India	x		Yes	130 students	Yes		x	x				Air Vel	
Kumar et al.	2016	India	x		Yes	32 buildings	Yes		x	x		x		Air Vel	
Liang et al.	2012	Taiwan	x		Yes		Yes								
Mishra and Ramgopal	2015	India	x		Yes		Yes		x	x				Air Vel	
Nematchoua et al.	2014	Cameroon	x		Yes	2650 surveys	Yes		x	x		x			
Ogoli	2007	Chicago/US	x		Yes	120 students	Yes		x	x				Air Vel	
Singh et al.	2018	India	x		Yes	30 classes, 3 uni	Yes		x	x				Air Vel	
Tell et al.	2013	UK	x		Yes	230 students	Yes								
Tribilcock et al.	2017	Chile	x		Yes	440 students	Yes		x	x				Air Vel	
Yang and Zhang	2008	China	x		Yes	11 Buildings	Yes		x	x				Air Vel	
Papazoglou et al.	2019	Greece	x		Yes		Yes		x	x				Air Vel	
Dias Pereira et al.	2014	Portugal	x	x	Yes		Yes								
Stazi et al.	2017	Italy	x	x	Yes	68 people	Yes		x	x		x			
Almeida et al.	2017	Portugal	x	x	No		Yes	8 schools	x	x	x	x			
Liu et al.	2019	China	x	x	Yes	3 universities	Yes		x	x		x		Air Vel	
De Guill et al.	2012	Italy	x	x	Yes		Yes		x	x		x		Air Vel	
Gao et al.	2014	Denmark	x	x	Yes	4 classrooms	Yes		x	x		x			

Table 1: Classification of the Literature Review

via opening windows (Bako-Biro et al. 2012). Different elements such as air ventilation systems, HVAC systems, building envelopes, and occupant behavior influence the condition of the indoor environment (Catalina and Lordache 2012).

Comfort is another factor, which is influenced by these building elements. Human comfort can be broken down into four conditions: thermal, visual, indoor air quality, and acoustical (Ortiz et al. 2017; Bluyssen 2009). Thermal comfort and indoor air quality are the most important of these four comfort conditions to address in improving occupant health and productivity (Pan et al. 2018). Several studies focus on these two elements and their relationship with operable windows in K-12 schools.

This paper synthesizes a total of thirty-one papers focusing on this subject. Gaps were found in the consistency of their methodology, transferability across their locations, the factors addressed in each of the research studies, and the sample size of the studies. All the identified literature used quantitative methods, including environmental monitoring, survey, and simulation. Also, most of the studies were located in Europe or Asia, with only one being conducted in the United States. Besides, only 21% of total (thirty-one) papers were focused on the relationship between operable windows and both thermal comfort and indoor air quality in K-12 classrooms; the rest focused on either thermal comfort or indoor air quality and their relationship with operable windows in K-12 classrooms.

A synthesis of the sensor measurement parameters across the studies, show all thermal comfort studies measured air temperature and relative humidity. Almost half of the studies measured air velocity as the primary indicator of thermal condition, while all the indoor air quality studies measured CO₂ levels as their metric. Furthermore, all the literature reviewed that used surveys as one of their methods asked questions of students, while it is teachers and school administrators that are in charge of opening or closing windows and of making policies related to using operable windows. For example, Coley and Beustein

(2002) state that some evidence shows that teachers and staffs are reluctant to open windows to improve ventilation and decrease CO₂ level because of: (i) a lack of awareness of the staff about the problem, and (ii) uneven natural ventilation drafts in the classroom. This literature review and synthesis establishes a gap in the samples showing that the teachers and school policy makers play an important role in using/not using operable windows in classrooms; these agents should be considered in the research design of future studies.

CONCLUSION

By synthesizing the literature review, several gaps were identified:

1. All the studies found addressing K-12 schools studied thermal comfort and indoor air quality from student's perspective, while teachers and school administrators oversee the use of windows.
2. All studies were conducted using quantitative methods, including environmental monitoring, survey, and simulation.
3. Only one study out of thirty-one was conducted in the U.S.
4. Only 21% of total papers addressing K-12 environments were focused on the relationship between operable windows and both thermal comfort and indoor air quality.

For future studies, mixed methods research is suggested to allow for more insight into the relationships between operable windows, thermal comfort, and indoor air quality in K-12 classrooms in the U.S. Interviews with teachers and school administrators are suggested for future research designs to better understand why they are or are not using windows, with environmental monitoring to measure temperature, relative humidity, air velocity, and CO₂ level. By implementing mixed methods studies in the U.S., a better understanding of these three considerations—operable windows, thermal comfort, and indoor air quality—can be harnessed to better support student health, wellbeing, and learning outcomes.

REFERENCES

- Abramson, S.L., A. Turner-Henson, L. Anderson, M.P. Hemstreet, S. Tang, L.K. Bartholomew, C.L.M. Joseph, S. Tyrrell, N.M. Clark, D. Ownby. 2006. "Allergens in school settings: results of environmental assessments in 3 city school systems." *Journal of School Health* 76, no. 6: 246–249.
- Almeida, R.M.S.F. and V.P. de Freitas, V.P. 2014. "Indoor Environmental Quality of Classrooms in Southern European Climate." *Energy and Buildings* 8: 127-140.
- Almeida, R.M.S.F., N.M.M. Ramos, and V.P. de Freitas. 2016. "Thermal Comfort Models and Pupils' Perception in Free-running School Buildings of Mild Climate Country." *Energy and Buildings* 111: 64-75.
- Andersen, R.V., J. Toftum, K.K. Andersen, B.W. Olesen. 2009. "Survey of occupant behaviour and control of indoor environment in Danish dwellings." *Energy and Buildings* 41, no. 1: 11-6.
- Annesi-Maesano, I., N. Baiz, S. Banerjee, P. Rudnai, S.G.S. Rive. 2013. "The Indoor air quality and sources in schools and related health effects." *J. Toxicol. Environment Health B* 16, no. 8: 491–550.

- ASHRAE Guideline 10P. 2010. *Interactions affecting the achievement of acceptable indoor environments*.
- ANSI/ASHRAE Standard 55. 2013. Thermal environmental conditions for human occupancy AHSRAE 55. ISSN: 1041-2336. ASHRAE, 2013.
- Bako-Biro, Z., D.J. Clements-Croome, N. Kochhar, H.B. Awbi, M.J. Williams. 2012. "Ventilation Rates in Schools and Pupils' Performance." *Building and Environment* 48: 215-223.
- Barrett, P, F. Davies, Y. Zhang, L. Barrett. 2015. "The Impact of Classroom Design on Pupils' Learning; Final Results of a Holistic, Multilevel Analysis." *Building and Environment* 89: 118-133.
- Bluyssen, P.M. 2009. *The Indoor Environment Handbook: How to Make Buildings Healthy and Comfortable*. London and Sterling, VA: Earthscan
- Buonocore, C., R. De Vecchi, V. Scalco, R. Lamcerts. 2019. "Influence of Recent and Long-term Exposure to Air-Conditioned Environments on Thermal Perception in Naturally Ventilated Classrooms." *Building and Environment* 156: 233-242.
- Brager, G., G. Paliaga, and R. de Dear. 2004. "Operable Windows, Personal Control, and Occupant Comfort." *ASHRAE* 110, part 2: 17-35.
- Catalina, T. and V. Iordache. 2012. "IEQ Assessment on Schools in the Design Stage." *Building and Environment* 49: 129-140.
- Chithra, V.S. and S.M. Shiva Nagendra. 2012. "Indoor Air Quality Inventigatoins in a Naturally Ventilated School Building Located Close to an Urban Roadway in Chennai, India." *Building and Environment* 54: 159-167.
- Coley, D.A. and A. Beisteiner. 2002. "Carbon Dioxide Levels and Ventilation Rates in Schools." *International Journal of Ventilation* 1, no. 1: 45-52.
- Daisey J.M., W.J. Angell, and M.G. Apte. 2003. "Indoor Air Quality, Ventilation, and Health Symptoms in Schools: An Analysis of Existing Information." *Indoor Air* 13, no. 1: 53-64.
- De Giuli, V., O. Da Pos, and M. De Carli. 2012. "Indoor Environmental Quality and Pupil Perception in Italian Primary Schools." *Building and Environment* 56: 335-345.
- Dhaka, S., J. Methur, A. Wagner, G.D. Agarwal, V. Garg. 2013. "Evaluation of Thermal Environmental Conditions and Thermal Perception at Naturally Ventilation Hostels of Undergraduate Students In Composite Climate." *Building and Environment* 66: 42-53.
- Dias Pereira, L., D. Raimondo, S.P. Corgnati, M.G. da Silva. 2014. "Assessment of Indoor Air Quality and Thermal Comfort in Portuguese Secondary Classrooms: Methodology and Results." *Building and Environment* 81: 69-80.
- Djamila, H. 2017. "Thermal Comfort in Naturally Ventilated Buildings in Maceio, Brazil." *AIP Conference Proceedings* 1903, 080009.
- Dorizas, P.V., M.N. Assimakopoulos, C. Helms, M. Santamouris. 2015. "An Integrated Evaluation Study of the Ventilation Rate, the Exposure and Indoor Air Quality in Naturally Ventilated Classrooms in the Mediterranean Region During Spring." *Science of the Total Environment* 502: 557-570.
- Fanger, P. Ole. 1970. *Thermal Comfort: Analysis and Applications in Environmental Engineering*. Copenhagen: Danish Technical Press.
- Fuoco, F.C., L. Stabile, G. Buonanno, C.V. Trassiera, A. Massino, A. Russi, M. Mazaheri, L. Morawska, A. Andrade. 2015. "Indoor Air Quality in Naturally Ventilated Italian Classrooms." *Atmosphere* 6: 1652-1675.
- Gao, J., P. Wargocki, and Y. Wang. 2014. "Ventilation System Type, Classroom Environment Quality and Pupils' Perception and Symptoms." *Building and Environment* 75: 46-57.
- Ge, A., G. Xu, H.J. Poh, C.C. Ooi, X. Xing. 2019. "CFD Simulations of Thermal Comfort for Naturally Ventilated School Buildings." *IOP Conference Series: Earth and Environmental Science* 238 012073.
- Griffiths, M. and M. Eftekhari. 2008. "Control of CO₂ in a Naturally Ventilated Classroom." *Energy and Buildings* 40, no. 4: 556-560.
- Jiang, J., D. Wang, Y. Liu, Y. Xu, J. Liu. 2018. "A Study on Pupils' Learning Performance and Thermal Comfort of Primary Schools in China." *Building and Environment* 134: 102-113.
- Jindal, A. 2018. "Thermal Comfort Study in Naturally Ventilated School Classrooms in Composite Climate of India." *Building and Environment* 142: 34-46.
- Krawczyk, D.A., A. Rodero, K. Gladyszewska-Fiedoruk, A. Gajewski. 2-16. "CO₂ Concentration in Naturally Ventilated Classrooms Located in Different Climates-Measurements and Simulations." *Energy and Building* 129: 491-498.
- Kumar, S., J. Mathur, S. Mathur, M.K. Singh, V. Loftness. 2016. "An Adaptive Approach to Define Thermal Comfort Zones on Psychometric Chart for Naturally Ventilated Buildings in Composite Climate in India." *Building and Environment* 109: 135-153.
- Lai, A.C.K., K.W. Mui, L.T. Wong, L.Y. Law. 2009. "An evaluation model for indoor environmental quality (IEQ) acceptance in residential buildings." *Energy and Buildings* 41: 930-6.
- Liang, H.H., T.P. Lin, R.L. Hwang. 2012. "Linking Occupants' Thermal Perception and Building Thermal Performance in Naturally Ventilated School Buildings." *Applied Energy* 94: 355-363.
- Liu, J., X. Yang, Q. Jiang, J. Qiu, Y. Liu. 2019. "Occupants' Thermal Comfort and Perceived air Quality in Natural Ventilated Classrooms During Cold Days." *Building and Environment* 158: 73-82.
- Madureira, J., M.C.M. Alvim-Ferraz, S. Rodrigues, C. Goncalves, M.C. Azevedo, E. Pinto, O. Mayan. 2009. "Indoor Air Quality in Schools and Health Symptoms among Portuguese Teachers." *Human Ecological Risk Assessment* 15:1: 159-169.
- Martinez-Molina, A., P. Boarin, I. Tort-Ausina, J.L. Vivancos. 2017. "Post-Occupancy Evaluation of a Historic Primary School in Spain:

Operable Windows, Thermal Comfort, and Indoor Air Quality in K-12 Schools

- Comparing PMV, TSV and PD for Teachers' and Pupils' Thermal Comfort". *Building and Environment* 117: 248-259.
- Mendell, M.J., E.A. Eliseeva, M.M. Davies, M. Spears, A. Lobscheid, W.J. Fisk, M.G. Apte. 2013. "Association of Classroom Ventilation with Reduced Illness Absence: A Prospective Study in California Elementary Schools." *Indoor Air* 23: 515-528.
- Mendell, M.J. and G.A. Heath. 2005. "Do Indoor Pollutants and Thermal Conditions in Schools Influence Student Performance? A Critical Review of the Literature." *Indoor Air* 15: 27-52.
- Mendes, A., D. Aelenei, A.L. Papoila, P. Carreiro-Martins, L. Aguiar, C. Pereira, P. Neves, S. Azevedo, M. Cano, C. Proenca, et al. 2014. "Environmental and Ventilation Assessment in Child Daycare Centers in Porto: The Envirh Project." *J. Toxicol. Environ. Health A* 77, no. 14–16: 931–943.
- Mishra, A.K. and M. Ramgopal. 2015. "A Thermal Comfort Field Study of Naturally Ventilated Classrooms in Kharagpur, India." *Building and Environment* 92: 396-406.
- Nematchoua, M.K., R. Tchinda, P. Ricciardi, N. Djonguang. 2014. "A Field Study on Thermal Comfort in Naturally-Ventilated Buildings Located in the Equatorial Climate Region of Cameroon." *Renewable and Sustainable Energy Reviews* 39: 381-393.
- Ogoli, D.M. 2007. "Thermal Comfort in Naturally Ventilated Educational Building." ARCC Spring Research Conference, Oregon, April 16-18, 2007. *ARCC Journal* 4, no. 2: 19-25.
- Ortiz, M.A., S.R. Kurvers, P.M. Bluyssen. 2017. "A Review of Comfort, Health, and Energy Use: Understanding Daily Energy Use and Wellbeing for the Development of a New Approach to Study Comfort." *Energy and Buildings* 152: 323-335.
- Pan, S., Y. Xiong, Y. Han, X. Zhang, L. Xia, S. Wei, J. Wu, M. Han. 2018. "A Study on Influential Factors of Occupant Window-Opening Behavior in an Office Building in China." *Building and Environment* 133: 41-50.
- Papazoglou, E., K.P. Moustiris, K.S.P. Nikas, P.T. Nastos, J.C. Statharas. 2019. "Assessment of Human Thermal Comfort Perception in a Non-air-conditioned School Building in Athens, Greece." *Energy Procedia* 157: 1343-1352.
- Peled, R. 2011. "Air pollution exposure: who is at high risk?" *Atmos. Environ.* 45: 1781–1785.
- Pereira, L.D., D. Raimondo, S.P. Corgnati, M.G. da Silva. 2014. "Assessment of Indoor Air Quality and Thermal Comfort in Portuguese Secondary Classrooms: Methodology and Results." *Building and Environment* 81: 69-80.
- Rackes A. and M.S. Waring. 2013. "Modeling Impacts of Dynamic Ventilation Strategies on Indoor Air Quality of Offices in Six US Cities." *Building Environments* 60: 243-253.
- Santamouris M., A. Synnefa, M. Assimakopoulos, I. Livada, K. Pavlou, M. Papaglastra. 2008. "Experimental investigation of the air flow and indoor carbon dioxide concentration in classrooms with intermittent natural ventilation." *Energy Building* 40, no. 10: 1833-43.
- Selgrade, M.K., C.G. Plopper, M.I. Gilmour, R.B. Conolly, B.S. Foos. 2008. "Assessing the Health Effects and Risks Associated with Children's Inhalation Exposures—Asthma and Allergy." *J. Toxicol. Environ. Health A* 71: 196–207.
- Singh, M. K., S. Kumar, R. Ooka, H.B. Rijal, G. Gupta, A. Kumar. 2018. "Status of Thermal Comfort in Naturally Ventilated Classrooms During the Summer in the Composite Climate of India." *Building and Environment* 128: 287-304.
- Stabile, K., M. Dell'Isola, A. Russi, A. Massimo, G. Buonanno. 2017. "The Effect of Natural Ventilation Strategy on Indoor Air Quality in Schools." *Science of the Total Environment* 595: 894-902.
- Stazi, F., F. Naspi, G. Ulpiani, C. Di Perna. 2017. "Indoor Air Quality and Thermal Comfort Optimization in Classrooms Developing an Automatic System for Windows Opening and Closing." *Energy and Building* 139: 732-746.
- Suk, W.A., K. Murray, and M.D. Avakian. 2003. "Environmental Hazards to Children's Health in the Modern World." *Mutation Research* 544: 235-242.
- Teli, D., P.A.B. James, M.F. Jentsch. 2013. "Thermal Comfort in Naturally Ventilated Primary Classrooms." *Building Research & Information* 41, no. 3: 301-316.
- Trebilcock, M., J. Soto-Munoz, M. Yanez, R. Figueroa-San Martin. 2017. "The Right to Comfort: A Field Study on Adaptive Thermal Comfort in Free-Running Primary Schools in Chile." *Building and Environment* 114: 455-469.
- U.S. General Accounting Office. 1995. *School Facilities: Condition of America's Schools*. Washington DC: U.S. G.A.O.
- Wang, Y., F.Y. Zhao, J. Kuckelkorn, X.H. Li, H.Q. Wang. 2014. "Indoor Air Environment and Night Cooling Energy Efficiency of a Southern German Passive Public School Building Operated by the Heat Recovery Air Conditioning Unit." *Energy and Building* 81: 9–17.
- Wargocki, P., J. Sundell, W. Bischof, G. Brundrett, P.O. Fanger, F. Gyntelberg, S.O. Hanssen, et al. 2002. "Ventilation and Health in Non-industrial Indoor Environments: Report from a European Multidisciplinary Scientific Consensus Meeting (EUROVEN)." *Indoor Air* 12, no. 2: 113-128.
- Yang, W. and G. Zhang. 2008. "Thermal Comfort in Naturally Ventilated and Air-Conditioned Buildings in Humid Subtropical Climate Zone in China." *Int J. Biometeorol* 52: 385-398.
- Zhang, G., C. Zheng, W. Yang, Q. Zhang, D.J. Moschandreas. 2007. "Thermal Comfort Investigation of Naturally Ventilated Classrooms in a Subtropical Region." *Indoor and Built Environment* 16, 2: 148-158.

THE BIRTH OF THE ORTHOGONAL CITY PLAN: Visual to Surveyed Representations of Rome from the 14th to 18th Century

Ayşe Aylin Tarlan
AA School

Abstract: Early representations of cities are shown as a staggering of selected icons, figures on a passive ground. Later in the seventeenth century, shifts in political governance lead to an increase of land value. At this point, representing cities in a visual manner is no longer efficient. A precise method is needed to record land in order to demarcate, manage, and mark ownership. With the discovery of measuring techniques and tools, cities are now surveyed and represented as an orthogonal projection. The evolution of this process takes place from the end of the Middle Ages until the nineteenth century. This paper traces back this evolution and focuses on examples that marked the transition from the visual representations to the orthogonal city plan, such as the Leonardo Bufalini plan of Rome and G.B. Nolli's *Nuova Pianta*, crucial orthogonal plan examples to assist with understanding this process. These orthogonal plans embed information on land economy in which figure, land, is equivalent to ground. They recall the origins of representing urban form as land registration that lie in the Roman jurisprudence. The first cadastral registry known is *Forma*, a bronze tablet used during the Roman colonization period. This document marks the beginning of representation of urban form as an abstract subject, an orthogonal projection with the intention of registering land use. In this paper, to better understand this evolution of representing the city as an abstraction, I will first look at early representations of Rome, where the origins of this transition have their roots. I will then proceed in unfolding political transformations that occurred during the transitioning periods, since it is this shift of power that leads to the necessity of recording land for renovation, fortification, and management purposes. For this, I will investigate the Leonardo Bufalini plan that applied in the 1551 survey to map the city of Rome. After Bufalini, orthogonal projection as a technique of representing urban form was not used until the 1700s when the city needed a series of renovation projects and land demarcation after the wars of reformation. The reintroduction of survey plans, and cadastral registry becomes an important tool for land management. Finally, I will end by analyzing Giambattista Nolli's *Nuova Pianta di Roma*, where this technique reached its peak in terms of accuracy as well as influence all over Europe.

Keywords: Representation, cities, orthogonal plan, figure ground, Nolli map.

INTRODUCTION

This paper studies the evolution of city representation from early visual drawings to the birth of the orthogonal city plan. It problematizes the process of prioritization while selecting information to be shown or omitted and the reasons behind it. In early representations, cities are shown as a staggering of selected icons, figures on a passive ground. These representations intended to give an idea of the city for the use of tourists and pilgrims, their main aim being the one of recognition and memory called *Memorabilia* (Bevilacqua and Fagiolo 2012, 53). Whether in the forms of ideograms, portraits, and bird's-eye view, these early representations maintain a visual character. In the beginning of the sixteenth century with the sack of Rome, the city remained destroyed until the Council of Trent consolidated the power of the papacy and restoration and initiated renovation projects to secure its authority, *Renovatio* (Maier 2015, 1-19). The shift of power leads to the necessity of recording land for management and ownership purposes. The

rediscovery and the introduction of the survey is an important act in this process. The origins of the survey lie in the Roman jurisprudence, *Forma* (figure 1), the first cadastral registry used to demarcate land during the Roman colonization period (Rykwert 1976, 60). For the Romans, land division and demarcation had an important role in management, control, and resolving conflicts. All survey techniques were very meticulously defined in the *Corpus Agrimensorum Romanorum* codex (Settis 2003, 103-119). Since the origins of *Forma* lie in the Roman jurisprudence, it is only logical to look at the evolution of representation of the city in Rome. Also, because it is a city with a very unique topography, Rome is extremely difficult to represent. From early representations, we note that Rome is described, experienced, and planned in elevation due to its fragmented nature. The transition from the visual representation of this irregular scenography to the abstract orthogonal projection is of great importance.

It is marked by historical and political events, as well as by the accomplishment of major plans at the same time. Many artists and architects were engaged in the rediscovery of survey techniques and their use in representing the city accurately (Bevilacqua and Fagiolo 2012, 23-61). The survey became even more useful for fortification projects with the rise of measurement in artillery (Germino and Johnston 2009, 31-44). Leonardo Bufalini was the first to apply this technique in 1551 (figure 2) to measure and represent Rome (Bevilacqua and Fagiolo 2012, 23-61). After Bufalini, orthogonal projection was not used until the eighteenth century, when the city needed a series of renovation projects and land demarcation after the wars of reformation. It is with Giambattista Nolli's *Nuova Pianta di Roma* that this technique reached its peak in terms of accuracy, as well as influence all over Europe (Bevilacqua and Fagiolo 2012). To investigate this phenomenon, I will first look at early representations, from ideograms to city portraits, then follow with accurate representations for restoration, renovation, and military defensive projects with the example of Bufalini's map. I will finally end with reintroduction of the survey, the cadastral map, and the example of Nolli Plan (figure 3).

1. EARLY IDEOGRAMS TO CITY PORTRAITS

There is an overabundance of representations of Rome over time. Early representations are mainly in the form of ideograms aiming to give an idea or an image of the city. Ideograms are abstract representations of urban form that show the outline of landmarks and diagrams of itineraries mostly for tourists and pilgrims (Bevilacqua and Fagiolo 2012, 23-61). They aim to help them guide their way through the city and give them a sensation of familiarity and direction. This is a process called *Memorabilia*, which can be understood as recognition or memory. These representations were made with either vertical figures or horizontal planimetric form. An example of this is the Fra Paolino map of Rome, *Chronologia Magna* (figure 4) from 1320 (Maier 2015, 19-23). As the name suggests, it is a chronological diagram in which the city is mapped through its churches, main buildings, houses, and streets in an undifferentiated Ground. The Fra Paolino's map of Rome lacks scale or any references to measured data, and its representation of monuments and streets remains illustrative. Later, the same format is seen in Bartolomeo Marliano's ideogrammatic view (figure 5), which presented the town as a collection of isolated monuments within a schematic rendering of the walls (Bevilacqua and Fagiolo 2012, 23-61). The ideogram had origins in antiquity; for example, it is seen in the gothic manuscript illustrated by the Limburg Brothers for the Duke of Berry (figure 6). This book, *Très Riches Heures*,



Figure 1: Forma. Musée Municipal d'Orange (Salvatore Settis 2003)



Figure 2: Pianta di Roma. British Library (Leonardo Bufalini 1551)



Figure 3: Nuova Pianta di Roma. AA Library (Giovanni Battista Nolli 1745)

regrouped several prayers and daily readings similar to a book of hours, in which appeared an iconographic descriptive miniature, for instance of the city of Rome (Nuti 1996, 43-47). In the late Middle-Ages, it evolved to include the forms of individual structures with an emerging desire to give their relative position and to incorporate some topographical features.

Another visual representational technique was called the city portrait. It usually had a circular form and gave a semi-realistic sense of the city (Nuti 1996, 43-67). These representations show important landmarks as figures in an omitted ground. The process of prioritization here consists of a selection of the figures, the icons. Only the important ones for pilgrimage and the itineraries of the *Grand-Tour* were chosen (Nuti 1996, 43-67). As a representational technique, the city portrait showed the figures in a central position and their dimensions had relational proportions. They served to promote Rome as *Caput Mundi* to the world. Therefore, they became a tool for propaganda, placing Rome as the center of cultural heritage and celebration of Christian power (Maier 2015, 1-19). For this reason, portraits were commonly used and as Lucia Nuti writes, "In all these cases the eyes of the observer are pointed to look for a selection of information that becomes a representation of the real" (Nuti 1996, 12).

They remained visual representations, which was useful for them to accomplish their purpose efficiently. The importance here was not to realistically show the urban texture of the city, but to create an illusion of the image of the city. They were realized by using different materials such as seals, frescos, paintings on canvas or woodcuts, also called xylography. A famous example that illustrates the technique of Portrait is the seal of Ludovico II Bavaro made in 1327 (figure 7) after the declaration of his imperial authority (Nuti 1996, 43-67). Here, Rome is represented in a circular form with an accumulation of selected figures such as the fortress, *Castello*, the circular polygonal walls of fortification, urban texture with staggered buildings, and the symbolic presence of the *Colosseo*. Once completed, this seal became a recognizable image of the capital, with the figures representing its main landmarks, walls, and topography distorted to serve the purposes of propaganda (Maier 2015, 1-19). There is a process of prioritization in the making of these representations in which the figures are either exaggerated, compressed, or drastically reduced to serve the means of promotion. Another example of a city portrait would be the Taddeo di Bartolo view of Rome from 1414 (Nuti 1996, 43-67). Again, the city is represented in a circular form with its buildings, the background almost irrelevant. Similarly, Pietro del Masazio's plan of Rome from 1471 illustrates this pilgrimage and other touristic itineraries (Nuti 1996, 43-67).



Figure 4: Chronologia Magna Map of Rome. Vatican Library (Fra Paolino da Venezia 1320)



Figure 5: Urbis Romae Topographia. Columbia University Avery Architectural and Fine Arts Library (Bartolomeo Marliani 1545)



Figure 6: Très Riches Heures du Duc de Berry. British Library (Limbourg Brothers 1412-16)

These representations are overruled by the icons serving the purpose of *Memorabilia* (Bevilacqua and Fagiolo 2012, 23-61). They characterize the representational system of the period of the fourteenth and fifteenth century. Beyond the aim of recognition, portraits have a religious connotation to them as well. Circular representational technique alludes to a view of the totality of the city from above, as from God's eye, and its protection by the surrounding walls. Metaphorically, it alludes to antique pagan and Christian traditions. Oriental and Occidental Christian worlds elaborated variations of portraits during the Byzantine and Carolingian period (Nuti 1996, 48). However, if we look at the portrait's core purpose, it was to build familiarity, recognition, and a sense of safety using a visual technique. The city is seen as an isolated portion, visually recognizable and protected but without having



Figure 7: Bella D'oro. Archivio di Stato Rome (Ludovic the Brave 1328)



Figure 8: Cosmographia Universalis. Mario Bevilacqua (Sebastian Munster 1550)

an identity on its own, since all cities represented this way seem to have the same figures (icons). This desire enhances the necessity to see the whole of the city from above and leads to the development of the bird's eye view representational system, extremely popular at the time. Sebastian Munster's *Cosmographia Universalis* view of Rome (figure 8) is a great example that shows the axonometric drawing in formation (Bevilacqua and Fagiolo 2012, 23-61). Aspects similar to the portrait technique are kept, such as the visual character, the circular shape, the view of the whole from above, as well as the enhanced chosen icons or figures, unidentified remainder, and picturesque topography.

2. NECESSITY OF ACCURACY

2.1. MILITARY FORTIFICATION PROJECTS

Accuracy in the measure of artillery, lines of fire and the range of cannons made it possible to plan bastioned walls for fortifications purposes. A suitable accurate representational technique was needed in a military context for defensive purposes. This technique based on survey was first used for the realization of large-scale projects in Italy, where engineers were employed in the design of fortresses. The distinction between the design process and the execution of projects gave the drawing an important dual role as a tool for planning and as a method of communication between architects and others. Issues of fortification were very important at the time and this technique became a crucial instrument for the British Royal Office to oversee, strategize, and project interventions. It is used in England in the mid-sixteenth century to design the fortress of Portsmouth a stronghold near the Pale of Calais (Gerbino and Johnston 2009, 31-44). It was applied to angled bastions as well which required an intensive use of geometry to determine their size and angle (Gerbino and Johnston 2009, 31-44).

This technique was already popular in Italy, since the end of the fifteenth century. For instance, Pope Paul III planned to fortify the third-century Aurelian circuit with a belt of bastioned walls, although only the Vatican was completed in the end (Bevilacqua and Fagiolo 2012, 23-61). So, these maps had a great use in military projects thanks to their simplified representational system as a planimetric outline. Many artists of the time, Raphael being one of them, worked on ways to create measured drawings of the Roman ruins for their restoration and conservation. These drawings would be part of a larger project; an accurate measured map of the city (Maier 2015, 1-19). This way the city becomes an orthogonal projection on paper through a process of abstraction. The same technique was already used to whole cities by Leonardo da Vinci and Giuliano da

Sangallo respectively (figures 9 and 10) for the cities of Imola and Pisa (Nuti 1996, 43-67; Bevilacqua and Fagiolo 2012).

The role of the surveyor was taken over by geometers, engineers, and architects. It is not surprising that the military commander Cesare Borgia, son of Pope Alexander VI, commissioned Leonardo da Vinci, an engineer, architect, and expert in fortification, ballistics, hydrography, instruments, and weapons of war. Da Vinci, who was working under the Duke of Milan, Ludovico Sforza, moved to Imola to survey the city and plan a fortification system for the recently destroyed town (Bevilacqua and Fagiolo 2012, 63-95). With the new techniques in measurement and artillery, a precise fortification could be planned. Da Vinci completed a survey of the town showing the outline of the city, street structure, and property boundaries, which was interesting since the primary concern was the town fortification. Not much of his survey technique is shown in this final drawing, besides pen lines dividing the circle that frames the drawing. However the irregularities in the



Figure 9: Map of Imola. Royal Trust Collection (Leonardo da Vinci 1502)



Figure 10: Map of Pisa. Uffizi Florence (Giuliano da Sangallo 1512-13)

rectilinear street plan testify to the accuracy of the map. In his survey, da Vinci marks in the margins the distances and directions to other towns and cities around Imola.

This representational mode of the outline of the city, or an orthogonal projection, is the first known ichnographic plan in Renaissance. Soon, it became widely practiced among architects and engineers but remained less popular with the wider public.

This translation of the ground to the drawing as an orthogonal footprint takes reference from the Italian word *Pianta*, a measured ground plan similar to the perimetric survey plan. Another important example of the use of this technique in Italy is the plan of the city of Pisa by Giuliano da Sangallo 1512-13 (Nuti 1996, 43-67). The city had been under a rebellion against under-appreciated Florentine rulers and the wall of the old Florentine fortress facing the town was pulled down. In 1509, as a result of this act, the Florentine government sent Giuliano da Sangallo and his brother Antonio to the front as military engineers to re-plan the fortifications of the city. This survey was made as a visual record of a measured urban space. It is in the form of an outline of the city. Ground plans can be called graphic representations, as they show the horizontal arrangement of a building or a town drawn to scale, sometimes displayed in numeric or linear form. The Italian word *pianta*, meaning the sole of the human foot, is applied to architecture as the footprint of the building. As seen in the map of Pisa, the city is represented solely as an orthogonal outline, a ground plan with exact measurements made through an intensive work of surveying *in situ*. The city is represented as an abstract net of measured points, in which features have different qualities, some given more importance over others. Some areas appear to be carefully recorded, whereas others are fanciful representations. For instance, most blocks are simplified and outlined, devoid of any internal structure, with a few exceptions where rows of parcels are marked along the street front, or churches are recognizable by their transept or apses. Some architectural details are included like the stairs going up to a tower or down to the river, the number of piers of the bridges, the altars of some churches, and most of all the piers and the columns. The selection of architectural features does not seem exactly random—it shows us the intention of the plan. The plan was commissioned by the ruler for the specific purpose of fortification, but the presence of land demarcations indicates a tight relationship between map and land ownership. The intentionality in this type of representation separates it from the earlier visual examples. In these orthogonal projections of cities, what is valuable is the ground, land. There is a clear transition from the visual representation to this abstract representation, in which the Figure

Ground relationship is no longer associated with icons or landmarks but is linked to data, measurement, and embedded information on land economy.

2.2. RESTORATION OF RUINS AND RENOVATION PROJECTS

As previously explored, up to the sixteenth century, maps of Rome are mainly iconographic in character, either as an ideogram or as a portrait, their goal being to provide a tool for wayfinding and propaganda through selected icons. Representation at the time was not only an instrument for pilgrims and tourists, but also used for control of the image of the city as *Caput Mundi* (Maier 2015, 1-19). This is why the representational character remained purely illustrative and visual. In the Middle Ages, Rome was perceived as the capital of the cultural world, with its iconic buildings and religious power portrayed in its representations. However, in 1527, following the orders of Charles V, the imperial army sacked Rome as a reaction to the alliance formed between Pope Clement VII with France, England, Venice, and Florence. In eight days, thousands of churches, palaces, and houses were pillaged and destroyed. The city's pre-eminence as a Renaissance center had ended; its citizens and rulers had abandoned the city for safer and more prosperous regions. It was not until 1545 that the recently elected Pope Paul III, Alessandro Farnese, encouraged the beginning of the reformation movement (Bevilacqua 2004, 31-37). He convened the Council of Trent, which consolidated the power of papacy by revitalizing the Roman Catholic Church in many parts of Europe. Finally, Rome recovered; and a new era of construction began through the culmination of a vast series of ambitious projects of urban renewal, development, and expansion. An affluent and powerful papacy sponsors many of these projects with the aim of reestablishing the city as a world capital of culture, a hub of learning and the arts, and, above all, as a symbol of Catholic glory. Maps become an instrument of divulgation of this image and a tool of declaration of power sponsored by the popes, cardinals, and members of the religious order through specific projects. Pope Paul III, referred to as the patron of the arts, collaborated with many artists for the development of his projects to establish power and stability. For instance, he commissions Michelangelo to design and rebuild the *Campidoglio* at the top of the Capitoline Hill, Rome's civic center (Bevilacqua and Fagiolo 2012, 23-61). There is a constant intention to demonstrate power through new constructions and an interest in learning from Rome's cultural past. The eternal city is intended to become the capital of the ancient world, as well as of the new world. Therefore, restoration of the cultural heritage and remains of ruins became an important

issue. The interest in antiquity was shown in paintings, which were drawn according to illusionary semblances. These paintings could not be used to reconstruct the vanishing roman ruins on paper. A more accurate and scientific representational system was needed, as Raphael points out in a Letter to Pope Leo X:

I shall say what I think opportune so that all the measurements can be understood, and all the members of the building can be determined without error. The way the Architect draws buildings, then is divided into three parts. The first part is the plan what they mean is the flat drawing. The second is the exterior wall, with its ornaments. The third is the interior wall, also with its ornaments. (Maier 2015, 49-75)

In order to draw accurately, a method was needed that would permit one to measure and record these ruins. The survey, which was part of the roman technique as explained in the first chapter, had faded away by the Middle Ages, leaving the stage open for visual representations, such as portraits and bird's eye views. P.D.A. Harvey writes that the ancient roman tradition of representing urban form to scale died completely during the Middle Ages, with only one example being the famous St. Gall plan of the monastic complex (figure 11), akin to a miniature city (Maier 2015, 1-19). The traditional representations of towns, originally defined in Ptolemy's *Geographia*, consisted of world maps and representations of specific places and regions called *Choreographia* (Nuti 1996, 43-67). These had the characteristic of representing a place in an elevated bird's eye view showing a wider angle of the town. Although choreographies started as a measured survey, they still retained a picturesque quality. They remained a quantitative representation, in which figures of the town showing cities' landmarks, principal streets, city gates, landscapes, and neighboring villages were described. It was only with Leon Battista Alberti's treatise *Descriptio Urbis Romae* that surveying techniques were reintroduced in 1450. The method described in this treatise consisted of instructions for making a map of the city by plotting its monuments as points on a Euclidean grid (Maier 2015, 19-31). This technique served mainly to measure a structure by circumnavigating its perimeter, using a magnetic compass to note each orientation of the walls and calculating their length. Defining polar coordinates was limited to the walls and buildings of the city (figure 12) and, when applied to represent the city as a whole, was not very successful (Bevilacqua and Fagiolo 2012, 23-61).

With the rise of this method, the task of measuring and the role of the surveyor gains importance again (Crosby 1997, 3-19). This was a very important task that required knowledge in mathematics, geometry, and law. It also required specific instruments, from more simple ones such as the builder's square, level,

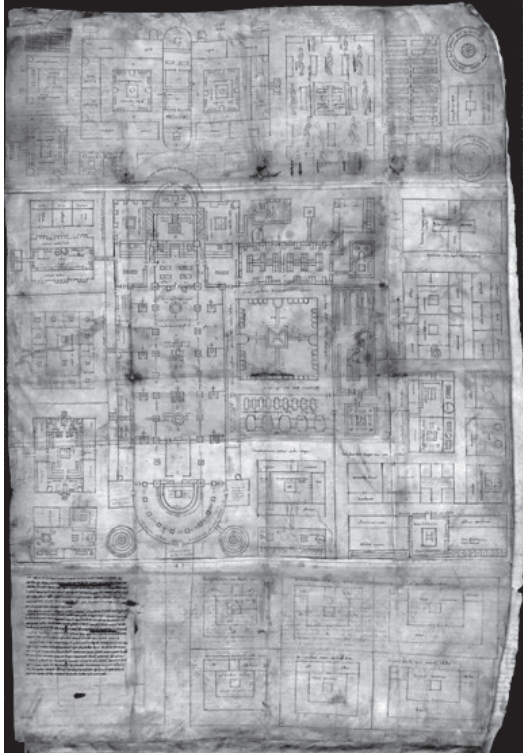


Figure 11: Saint Gall Monastery Plan. www.stgallplan.org (Reichenau 820-830)

and compass, to more sophisticated ones, such as the plane table. The resulting survey, when applied to the city, was a measured footprint, an orthogonal projection. This sort of representation was not only useful to record an existing building, or a set of antique remains, but also to accurately plan a renovation project. These accurate representations were also used for the making of projects on site. Projects tended to have a more geometrical character, in order to facilitate their construction, thus creating a tight link between measure, mathematics and geometry. In the Middle Ages, plans were used as a tool for the communication of an idea of the whole building and its parts, as a record of contract (Germino-Johnston 2009, 17-30). They did not show accurate measurements and were not used on site or for planning the design process. However, with the rediscovery of survey techniques, accurate plans permitted the making of planned buildings.

2.3. LEONARDO BUFALINI'S MAP OF ROME

This method was then applied for the first time by Leonardo Bufalini in 1551 to Rome, and it is the only surviving printed map of the eternal city (figure 2). It was commissioned by the patron of the city, Pope Julius III, and was dedicated to Charles V of Spain, as

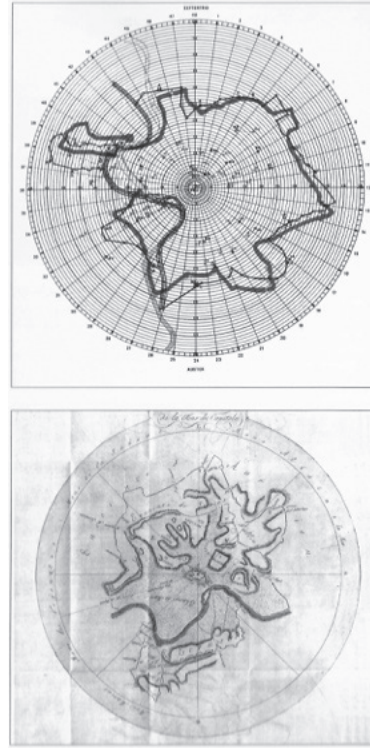


Figure 12: Descriptio Urbis Romae. Mario Bevilacqua. (Leon Battista Alberti 1451)

well as Henri II of France. Papal power was shifting and unsteady; balanced by other forces, the papacy consisted of a series of non-hereditary rulers, many of whom reigned only briefly and had disparate goals, or even worked at cross-purposes. Bufalini, a woodworker, engineer and surveyor from Udine was commissioned to undertake the making of this map. Although this map was issued for mainly military fortification purposes, it also revived a nostalgic, antiquarian aspect of the city. We see a horizontal ground plan of the modern city based on survey alongside the old city with the inclusion of ruins. In the collective pursuit of the investigation of antiquity of the time, ruins take on an important role in the map and are represented in their original state and not as remains. Leonardo Bufalini imposed symmetry by completing the plans of the fragmentary structures that were visible at the time. The importance of axial symmetry recalls the Vitruvian approach used by artists at the time in their reconstructions. Ruins are marked as figures on this map, floating on a semi articulated topography recalling the iconographic traditional representation. There is a dichotomy between the inhabited *intra-muros* of the city and the heritage of antiquity, the ruins (Maier 2005, 77-119). This juxtaposition makes the figure ground relationship in this map a dichotomy of two different entities. It shows

The Birth of the Orthogonal City

the attempts to make-Rome, not only the capital of the ancient world, but also of the modern one. The entire urban fabric including its streets, topography, natural features, and built environment are depicted in order to plan for new projects of expansion. In the early fifteenth century, the city was expanding and there was a need for more space for trades, animals, streets, markets, praying, and services outside of the church ceremonies and housing. The city grew beyond the borders and the predetermined walls (Bevilacqua and Fagiolo 2012, 23-61). An understanding of the land use becomes important, the topography as a base for new projects of expansion, as well as a document for juridical record. This surveyed representation of Rome, which started as an archeological record of historical remains, became an outline for expansion and renovation projects and fortifications (figures 13 and 14). It became a tool for the governing authority to plan projects, but also to demarcate land and secure ownership.

3. FROM CADASTRAL REGISTRY TO ORTHOGONAL MAPS

3.1. REINTRODUCTION OF SURVEY PLANS

After the making of Bufalini map, Rome went through ravaging times. By the beginning of the eighteenth century, the geopolitical situation in Europe becomes unstable with the conflicts between the Lutheran and Catholic Reformation. Finally, after thirty years of war, the peace of Westphalia was established, and Rome reached its artistic and urban splendor. The number of inhabitants in the city increased and its urban fabric flourished through a series of new expansion projects (Bevilacqua 2004, 31-37). However, in the mid-eighteenth century the prestige of Rome faced a decline. It was perceived as the capital of Christianity, stuck in the past and corrupt. The enlightenment ideology that dominated this period challenged the antiquarians for a more scientific and mathematical development of baroque Rome (Bevilacqua 1998, 65-80). This approach consisted not only in accurately measuring and representing the city, but also in understanding land use and value, because land had become the major factor of trade and production for the highly populated city. At the same time, land was a political tool of control and exertion of power of authorities over their city. So, in managing, expanding, and rebuilding, it became very important to have an adequate representational system. The survey was reintroduced to measure and represent land demarcation, ownership, and use and it resembled an outline of the city, a perimetrical cadastral registry. The roots of this registry and survey are attributed to the roman jurisprudence as discussed in the first chapter (figure 1). During colonization, the Romans used the



Figure 13: Bufalini Pianta di Roma. British Library London (Leonardo Bufalini 1551)

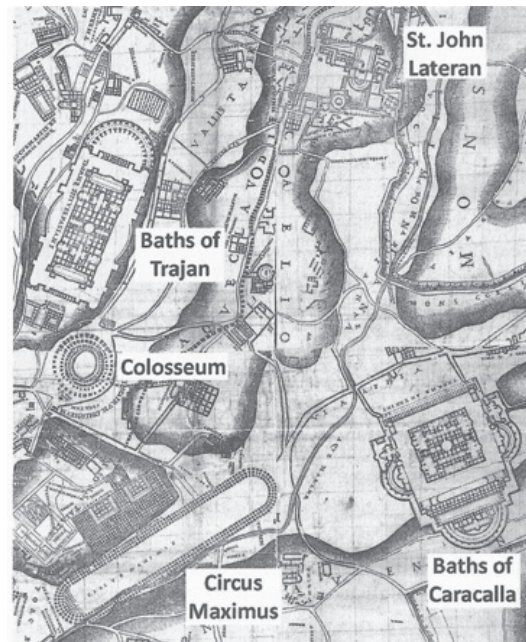


Figure 14: Bufalini Pianta di Roma. British Library London (Leonardo Bufalini 1551)

survey as a basis for cadastral registry to demarcate land and ownership. It was also very useful in case of conflict (Settis 1983, 72-85). So, registration of land for the purposes of demarcation and ownership was used in the form of a perimetric outline. It was used in England, in the early modern architectural practice, as well as for administrative responsibilities related to the care of estates. Indeed, the earliest masons' ordinance, the Cooke and Regius manuscript, dates from the late fourteenth and early fifteenth century, a book on the art of masonry and the science of geometry and survey. This mathematical culture was also seen

in Leonard Digge's *A Boke named Tectonicon*, dated 1556, that explained land and material survey (Gerbino and Johnston 2009, 45-49). This technique was fully applied to the remaking of the city of London after the fire of 1666, when the Society sought a rapid method to survey the city, in order to legitimize land ownership and start reconstruction projects immediately. As an example, Sir John Evelyn, founding member of the Royal Society, made a representation of a portion of his property (figure 15). It was then proposed by Christopher Wren, an enthusiast of this mathematical representation, and also a founding member of the Royal Society, in order to make a cadastral survey of the entire city (Gerbino and Johnston 2009, 95-96). John Ogilby and William Morgan, both engineers, were charged with undertaking this enterprise (Bevilacqua and Fagiolo 2012, 63-95). The entire city was surveyed, and the map was completed in 1676. It became a record of ownership through plots and lots, as well as a base for reconstruction projects (figure 16). This map was produced thanks to the surveyor, an expert in measuring land accurately and then transferring this data into an orthogonal representation of urban form. In this form of representation, figure ground becomes one abstract entity, the one of the measure or data, which demarcates land and indicates information on the ownership status.

3.2. CADASTRAL REGISTRY

The same logic of survey and an attempt at an orthogonal projection of the city is applied to Rome in 1723 in a period when Rome was caught in a destruction-reconstruction cycle, due to its unstable political organization. Only in the eighteenth century did Rome become more stable, as the alliances between the popes' families made it more governable. At this moment, the governing popes decided to focus on urban reform projects instead of building new monuments, in order to stabilize their power, almost as if the rulers' authority was transferred to the ground. The Nolli map was commissioned for the planning of these projects. This map was not a regular city map but an instrument for city management (figure 3). It aimed to reflect the stability of the papal estate and its government with expansion and renovation projects, making the city the capital of Christianity. Nolli was an engineer, architect, and surveyor from Como who was commissioned and sponsored by the Cardinals Albani and Baldani, Marquis Capponi and Corsini and The Baron Stosch and banker Belloni, the protagonists of the power structure of the time. This enterprise was led by Diego Revillas, cartographer and antiquarian who had worked with Nolli before in Milan (Bevilacqua 1998, 35-47). Nolli received his education in Milan and worked

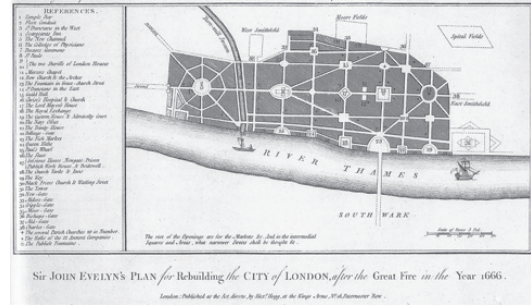


Figure 15: Sir John Evelyn Map of London. British Museum London (Sir John Evelyn Map of London 1666)



Figure 16: Morgan-Ogilby Map of London. British Library London (John Ogilby and William Morgan 1676)

at the *Cadastrò Teresiano* (figure 17) where he authored various works (Bevilacqua and Fagiolo 2012, 371-447). The *Cadastrò Teresiano* as explained in The Cadastral Map in the Service of The State was born:

"In the emergent societies of Renaissance Europe, where land became a commodity and power relations were expressed through control of the means of production, which included land, there was now clearly a reason for mapping properties- namely, as an aid to developing the new systems of exclusive rights to land" (Kain and Baigent 1992, 1-7).

The cadastral map was the result of a very precise survey and its representation as an outline of the city, a perimeter. It contained crucial information on land economy. In this concept, localized authority could measure and register properties and the increasing land led to the quantification of land as a commodity and claim taxation. Similar to the act of survey and the birth of the cadastral registry, quantification of land had its roots in the tradition of roman jurisprudence. In the roman law, *Corpus Iuris Civilis*, quantification of land was clearly defined; public and the private (Thomas 2002, 1431-5). These categories were useful to define an abstract value of things and to organize a sense of commerce and taxation policies. Territory was organized according to this law; delimitation of the ground was done in terms of in which category

it would be used. With this tradition, once surveyed land is registered into a cadastral map and its use is defined, it becomes possible to apply taxation policies. For instance, tax reform was applied in Italy in the state of Milan ruled by Charles VI and continued by his successor Maria Theresa of Austria (Kain and Baigent 1992, 175-95). It was an initiative that linked the ruling authority to the ground, creating an interdependence between measurement and power. Here we can say that measurement became a political gesture that incorporated law, mathematics, and trade. The use of the cadastral map was exactly the result of this initiative, a representational system that aimed to unite the land under a centralized authority, the ruler, who as decision maker empowered local estates to levy taxes. The link of authorities to the ground, based on a survey making land a commodity, entailed and benefited from a new set of rules. This tax reform, the *censimento*, marked a change of income from land different from the medieval period, which was not calculated by reference to area-based quotients, but derived from possession of rights over specific tracts of land (Kain and Baigent 1992, 175-95).

3.3. G.B. NOLLI NUOVA PIANTA DI ROMA

The *Nuova Pianta di Roma* was initiated with these principles in mind. It was a hybrid of the cadastral registry and earlier attempts at perimetric representation as the Severian Marble plan of Rome; *Forma Urbis Romae* and Leonardo Bufalini's plan of Rome (figure 2). It is defined as an orthogonal projection showing the link between land demarcation and production. In this context, it aimed also to show the archeological layer of the city in a period of decline, an attempt to renovate the city and maybe change its image too. It was made out of twelve copper plate engravings that together measures 176 centimetres (69 in) by 208 centimetres (82 in). The process consisted in a meticulous *ad vivum* survey of parcels of city drawn



Figure 17: Cadatro Teresiano. Archivio di Stato (G.B. Nolli 1722)

into a *disegno preparatorio* (Bevilacqua 1998, 65-83). The exactitude of this preparatory drawing was realized thanks to survey tools, as well as the invention of the plane table, *tavola pretoriana* that enabled drawing on site (figure 18).

The results of this survey were so accurate that the *Nuova Pianta di Roma* was used until the urban reforms of the twentieth century (Bevilacqua 1998, 65-80). A particularity of this representation, if we compare it to its precedent earlier attempts, is that beyond an outline or a cadastral registry, it also incorporated the plans of major buildings. Monuments such as churches, atria, internal courtyards, stairs and open spaces were represented in detail, as well as the ruins (figure 19). As in Leonardo Bufalini's map, Giambattista Nolli's *Nuova Pianta di Roma* started as an archaeological survey and ended by representing land economy. In this method, the striking relationship of figure ground lies on the fact that the built space is the figure becoming one with the ground. Almost as figure, the buildings and the land are represented as the same in this orthogonal projection. The dichotomy of the pair figure ground, black and white is emphasized by a new actor: the *poché*. It represents interiors as if a virtual cut was made into the built mass. In the Nolli map this technique is applied to the whole city, not only to prioritized buildings as in Bufalini (figures 2-3). So, the process of prioritization here concerns the whole city. The dichotomy is applied to the built mass

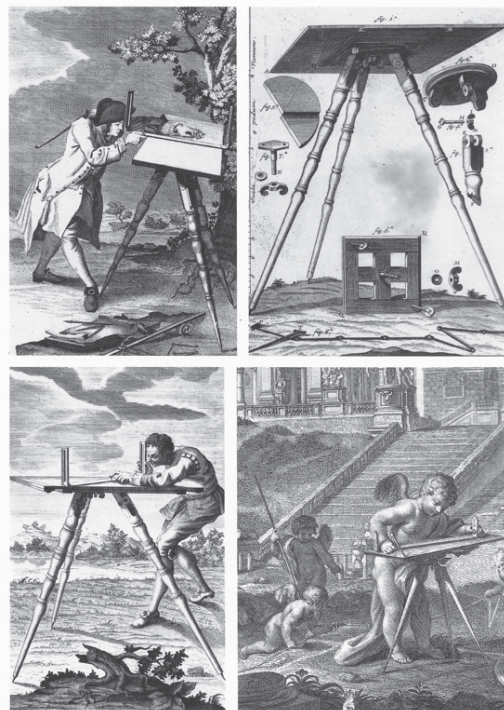


Figure 18: Plane Table. Mario Bevilacqua (G.B. Nolli 1722)



Figure 19: Detail Pianta Nuova. AA Library (G.B. Nolli 1722)

comprised of the architectural features against the unbuilt urban topography. This approach rejects the over simplistic understanding that we have of the Nolli map seen as an illustration of the private over public. Some of the buildings that are shown, that according to this approach, would be considered public (such as church courtyards for instance), are in fact private. Hence this point also reinforces the argument of this paper, which shows the use of this map as an instrument for land management, a tool to plan projects and economy. So here figure ground is the technique that permits the separation of the architectural from the urban. Hence it is an indicator of fixed features seen in *poché* over the ones enabling a possible reform represented in black. Also, the land for production is carefully denoted (figure 20) and the figure ground representation becomes a tool for management of the agricultural abundance (Marin 2001, 201-18). After the making of this map, which was a very tedious and expensive venture, it was promoted and copied in important cities all over Europe as the model to follow.

CONCLUSION

In this paper, I aimed to look at the evolution from the early representation of cities, specifically of Rome, to those completed in the eighteenth century and the influences behind their evolution. There is a clear transition from a visual to a surveyed representation. It is guided through its purpose and reflects the authority governing the city as representations of cities become a political gesture, a link between the governmental authority and the ground. Early representations fulfilled a visual character for the purpose of recognition and tourism. Landmarks and important icons were prioritized and become the figure over an omitted ground. These representations whether as a portrait, an ideogram or a bird's eye view, maintained an iconographic figure ground character. With the rising needs of military fortification projects



Figure 20: Detail Pianta Nuova. AA Library (G.B. Nolli 1722)

and the rediscovery of the survey, measured accurate maps were used first to plan and strategize defense. As seen with Leonardo Bufalini's plan of Rome, the survey becomes a tool for planning restoration, renovation, expansion and fortification projects. It starts as a cadastral survey map that shows the perimetric outline of the city and is very different from visual representations because it embeds information on land demarcation and ownership. It is used to both plan the city and to communicate with different parties involved in the decision making, execution and construction. Then, it evolves to become an orthogonal projection of the city as seen in the last example, the G.B. Nolli's *Nuova Pianta*. At this point, it is a definite tool used to manage the city. This orthogonal projection of the city creates an abstract link of power to the ground. Entities prioritized as figure or ground become the instrument of land management. The orthogonal map, an abstract figure ground dichotomy represents the production in the city a politico- economic project. It is used as a tool for land demarcation, ownership and taxation. The orthogonal map becoming a tool to quantify land and its commodities. The shift in representations and use also reflects the shifting governmental system behind it, from a centralized authority towards a system based on land quantification.

REFERENCES

- Bevilacqua, Mario. 1998. *Roma nel Secolo dei Lumi: Architettura Erudizione Scienza nella Planta di G.B. Nolli "Celebre Geometra."* Rome: Electa Napoli.
- Bevilacqua, Mario. 2004. *Nolli Vasi Piranesi: Immagine di Roma Antica e Moderna, Rappresentare e Conoscere la Metropoli dei Lumi.* Rome: Artemide.
- Bevilacqua, Mario and Marcello Fagiolo. 2012. *Planta di Roma: Dal Rinascimento ai Catasti.* Rome: Artemide.
- Kain, Roger J. P. and Elizabeth Baigent. 1992. *The Cadastral Map in the Service of the State: A History of Property Mapping.* Chicago and London: The University of Chicago Press.
- Maier, Jessica. 2015. *Rome Measured and Imagined: Early Modern Maps of the Eternal City.* Chicago and London: The University of Chicago Press.
- Rykwert, Joseph. 1976. *The Idea of a Town.* London: Faber Finds.
- Settis, Salvatore. 2003. *Misurare la Terra: Centurazione e Coloni nel Mondo Romano.* Modena: Franco Cosimo Panini.
- Gerbino, Anthony and Stephen Johnston. 2009. *Compass and Rule: Architecture as Mathematical Practice in England 1500-1750.* New Haven and London: Yale University Press.
- Marin, Louis. 2001. *On Representation.* Translated by Catherine Porter. Stanford: Stanford University Press.
- Nuti, Lucia. 1996. *Ritratti di Città: Visione e Memoria tra Medioevo e Settecento.* Venice: Marsilio.
- Crosby, Alfred W. 1997. *The Measure of Reality: Quantification and Western Society, 1250-1600.* Cambridge: Cambridge University Press.
- Thomas, Yan. 2002. "La Valeur des Choses: Le Droit Romain Hors la Religion." *Annales HSS* 57, no. 6 (Nov-Dec): 1431-5.

ON SOLIDITY IN ARCHITECTURE: Ornament, Shadow, and Construction

Laura Trazic
Ecole Polytechnique Fédérale de Lausanne

Abstract: This paper investigates the divergent and conflicting effect of both ornament and its shadow on traditional architectural solidity. Classical ornament is well-known to support the constructive idea of an edifice. Its main elements and patterns, from the column to the entablature, have throughout the centuries conveyed the idea of its constructive system. Treatises, beginning with Vitruvius' *De Architectura*, codified its proportions and disposition on key places of the façade in order to appraise, at first glance, the architectural solidity. Whatever may be the style—Doric, Ionic or Corinthian—whatever may be the purpose—church or palace—the mouldings and sculptures are deployed in an overall decorative system which should be in adequacy with the constructive idea.

Yet, as architects systematized sculptural ornaments, they could not but face an inherent difficulty induced by the relief itself: its own cast shadow. If sculptural ornament is supposed to reveal tectonics and solidity, its shadow may have the power to affect the latter. How is it that a mere shadow, ever-changing and moving on the façade, could endanger the solidity of a building and the mass and weight of the stones?

Based on architecture treatises, this paper will focus on a critical gap between two stances. First, we shall observe how Vitruvius and Alberti linked solidity with ornaments and their shadows, and if it was even of importance for them. A second step shall bring us a few centuries later in the French eighteenth century, when architecture borrowed from painting theories the question of aesthetic shadow. Beforehand, definitions of the three terms used—solidity, ornament, and shadow—may be useful to capture how shadows put at risk architectural solidity.

Keywords: Shadow, ornament, decorative system, solidity

INTRODUCTION

Vitruvius and Alberti agreed on the fact that the three principles of architecture—beauty, utility, and solidity, are fundamentally intertwined. Whether it comes to the Vitruvian *firmitas-utilitas-venustas* or the Albertian *soliditas-comoditas-voluptas*, “these qualities are so closely related that if one is found wanting in anything, the rest will not meet with approval” (Alberti 1988, VII-1, 189). Although *solidity* and *beauty* seem diametrically opposed from each side of the triad, they are intrinsically intertwined. From the fulfillment of their own conditions depends their respective and mutual achievement and the praise the edifice might eventually receive. In order to meet the requirements for these two principles, architects have at their disposal a range of traditionally theorized conventions. In fact, the strong link between construction and beauty is deeply rooted in the discourse on orders and ornaments, since a well-designed ornamentation—through the proportion and disposition of its elements—is seen as the key to convey at once the beauty and the constructive idea. The harmony of the composition depends mainly on a balanced ratio between voids and solids.

Yet, as ornaments are ruled by a system of proportions that define their heights, widths, and depths, they naturally cast shadows over the façade's main plan. The question raised at this point could be the

following: *do the shadows cast by ornaments interfere with the solidity that they are simultaneously supposed to achieve, and how could this happen?*

The research will be conducted through theoretical writings so as to reveal if shadow has ever been of concern and if its hypothetical link with solidity has been addressed or, at least, noticed in traditional architectural theory. The first place to find the premise of an answer is in the Vitruvian and Albertian treatises. The second historical period the study investigates will be the French Enlightenment. As a matter of fact, architects of the eighteenth century faced a crisis in their practice, since the rise of structural engineering forced them to reconsider their discipline and to reinterpret architecture foundational principles. Solidity was then a major issue to address, and the topic of shadow in architecture increased exponentially in parallel during that period.

A second part will investigate how Vitruvius and Alberti did conceive the link between solidity, ornament, and shadow, if at all, and a third part will explore the views of the French Enlightenment's architects. Beforehand, we will briefly present the three studied protagonists that compose the object of this study, namely the principle “solidity”, the object “ornament”, and the phenomenon “shadow”.

1. SOLIDITY, ORNAMENT, AND SHADOW

1.1. SOLIDITY IN ARCHITECTURE: TO BE AND TO SEEM

The notion of solidity links, as the two sides of a same coin, two physical aspects of the building. To ensure a lasting stability to the latter, the notion gathers both a technical and an aesthetical aspect: the efficiency and assemblage of employed materials and also their dimensions and positions. The second aspect relies on the application of the rules of proportion established since Vitruvius, and on a very long tradition of construction experience. These two aspects evolve jointly and depend as much on the construction's scientific objectivity as on the subjectivity of human perception. Solidity must then follow two imperatives: not solely that the architectural object has to *be* solid, but also that it has to *seem* like it is.

Solidity therefore implies a proportional system that codifies the geometry of constructive elements themselves according to their materiality—height, breadth, depth—and the geometry of each element with respect to the others, including the voids that separate them, as do the different styles of intercolumniation. Homothecy is the main mathematical operation that maintains the system whose module is usually “taken from the diameter at the base of the column” (Alberti 1988, VII-7, 202). If the architect chooses to step out of the conventional proportional system, the conceived edifice is exposed to the possibility of looking less solid and less beautiful.

1.2. PROPORTIONS OF THE ORDERS: HEIGHT, WIDTH AND DEPTH OF ORNAMENTS

The realm of appearance reigns over structural qualities as over any decorative system. Actually, trying to distinguish them would be unsuccessful and for Alberti, such a distinction simply did not exist. Ornaments compose orders, which participate in proportioning and articulating the masses. Columns, entablatures, or even to a lesser extent, every bracket, baluster, volute, and sculpture aim to tell the narrative of construction through their disposition according to key tectonic parts of the façade. Among these listed ornaments, columns, entablature, and moldings are governed by well-defined proportion rules whereas the other elements offer a greater freedom (*licentia*) with regard to their forms and dimensions (Payne 1999, 1). Each order may be recognized through specific ratios applied to their height, breadth, and depth. This latter is given according to a reference surface, usually the wall, and applies to all protruding or recessing ornaments. These reliefs may either keep a physical contact with the wall, such as high or bas-reliefs, or they may be completely detached, such as round sculptural figures or free columns. Depth

completes the proportional definition of orders, even though it cannot be understood as a strict differentiating feature since, regardless of the order, overall projections are limited to 45°, which means that their maximal depth must not exceed their height as Alberti states, “‘Cornice’ we call the top section, protruding above the rafters. The general rule given for all projections also applies here, in that the distances that any section projects from the wall must also equal its height.” (Alberti 1988, VII-9, 210)

So far, we have seen that, first, solidity traditionally depends on the proportions of orders, and, second, that these orders present a relief which depth is also theorized. As the façades are to be exposed to sunlight, whose rays' strength depends on climatic conditions, their ornaments naturally cast shadows on themselves according to their orientation.

1.3. THE SHADOW, PHENOMENON, OR OBJECT?

The French word *ombre* eludes the distinction that can be found in English between shade and shadow, a distinction that does not refer to its nature (shades and shadows are both the product of a physical phenomenon and their very existence relies on light and on an obstacle that blocks its rays), but renders better its double perception: shade is atmospheric and quantitatively undefined, while shadow may be perceived as a countable object, even though abstract. The shadow's reification must not distract from its necessities: even though it ever-moves uncontrollably over surfaces it does not belong to, shadow is always attached to an object (Arnheim 1974, 315). This is the specific case of the *cast shadow*, unlike the *core shadow* that sticks to the object's body.

How could such a phenomenon affect the solidity; how could it put at risk the mass and weight of a construction made of stones, bricks, wood or metal? In 1990, when Arden Reed wrote, “It might seem that to talk about architecture and shadows automatically means to talk about solidity and vacuity, or presence and absence” (15), his intuition lent to shadow some power over architectural solidity. The structural fiction built according to specific proportions could be disturbed by their modification. Since solidity relies on a proportional system, shadows might interfere by a modification of the beholder's perception of voids and solids: a darkened surface may instead appear as a void. Eventually, it seems that shadows have the power to hack the reading of solidity. Paradoxically, it is the set of ornaments arranged to support the narrative that invites the hackers in. The two following parts will highlight how the phenomenon has been acknowledged by Vitruvius, Alberti, and French architects of the eighteenth century, and discuss the ornaments that have been specifically pointed out.

2. THE FIRST APPREHENSIONS: ORNAMENTS' SHADOWS FOR VITRUVIUS AND ALBERTI

2.1 THE FUNCTION OF SHADOW IN THE VITRUVIAN AND ALBERTIAN DISCOURSES

The matter of shadow and darkness represents different concerns for the theoreticians. For Vitruvius, shadows are mainly related to the gnomonic (*gnomonica*), one of the three components of architecture, along with the edification (*aedificatoria*) and the construction of machines (*machinatio*) (Cache 2019, 16-32). In his *De re aedificatoria*, Alberti's shade is either a matter of climatic ambiance of an area delimited by walls¹, or it is given a hint of sublime aesthetics with the exaltation of religious feeling through the darkness of a temple.² Alberti wrote treatises on both architecture and painting. It is only in his *De pictura* that he had to confront the problem of shadows. The author built connections between these two arts on the terrain of beauty and ornaments. He directly announced to the readers of the *De re aedificatoria*, at the beginning of the seventh book on ornaments of sacred edifices, "Our inquiry will prove so valuable that not even painters, who are the most exacting seekers of delight, would be without it; it will also prove so delightful that—to put it simply—you will not regret having read it." (Alberti 1988, VII-1, 189)

In the opposite manner, the wording in the *De Pictura* differs, "Only from the painter himself, if I make no mistake, the architect took in fact the architraves, the capitals, the bases, the columns, the pediments, and all other similar ornaments of the edifices" (Alberti 2011, II-26, 45-6).

2.2. ALBERTIAN SOLIDITY AND THE SCOTIA

Shadow is not a threat for the Albertian solidity. The constructive fears expressed by the architect are much more directed towards overhanging members, which he exhorts the reader to avoid.³ However, one specific molding, part of the column base, drove Alberti to make a comment: "The scotia is a circular recess, like that in the wheel of a pulley, sandwiched between the tori." (1988, VII-7, 202) Such a recess at the base of the column is enough to worry Alberti, who immediately cleared the issue by determining its depth:

The scotia consists of a hollow channel and two thin fillets running around the edges of the channel. Each fillet takes up a seventh of the thickness; the remainder is hollowed out.

It is essential in all building, as we said, to take care that everything rests on a solid base. Nor will it be solid, if a plumb line dropped from any masonry above meets air or void. When carving out the channel of the scotia, they were always careful not to cut beyond the vertical of whatever was built on top. The tori projected five eighths of their thickness; and the thicker torus at its widest point was aligned with the profile of the die within the base. So much for the Doric.

The Ionians found the thickness of the Doric base to their liking, but doubled the number of scotias, and added two thin rings in the middle, between the scotias. (1988, VII-7, 203)

In his annotated translation of Vitruvius republished in 1684, Claude Perrault clarified, "The Greek word *Scotos* means darkness. The recessed part of the base is called *Scotia*, because it is the most shaded." (Perrault 1684, 90)⁴ It is mainly the word *scotia* that prevailed in architectural French literature, and its etymology was invariably recalled to underline its shadow-making function.

Scotia combines in one ornament both the visual experience of shadow and the perception of its void. Not only did shadow give its name to a significant molding, but it also became an architectural substance.

2.3. VITRUVIUS AND THE DIMINISHING EFFECT OF LIGHT

The case of the scotia is that of a core shadow, cast by a volume on its own body and which, when too dark, put at risk the constructive idea of stacked masses, such as a shaft over its base. The cast shadow was also noticed for the very same effect later on by Perrault in his translation of Vitruvius, regarding the *Aerostyle* intercolumniation.

In the original text, Vitruvius expressed his concern regarding the visual effect of a strong light on columns' form readability in general and their thickness in particular:

For the thickness of the shafts must be enlarged in proportion to the increase of the distance between the columns. In the *Aerostyle*, for instance, if only a ninth or tenth part is given to the thickness, the column will look thin and mean, because the width of the intercolumniations is such that the air seems to eat away and diminish the thickness of such shafts. . . . We must therefore follow the rules of symmetry required by each kind of building. Then, too, the columns at the corners should be made thicker than the others by a fiftieth of their own diameter, because they are sharply outlined by the unobstructed air round them, and seem to the beholder slenderer than they are. Hence, we must counteract the ocular deception by an adjustment of proportions. (Vitruvius 1960, III-3, 84)

In his translation, Perrault considered instead the role of shadow in this visual deception. He documented his disagreement with a drawing entitled *How light and shadows may make appear columns thicker or slenderer depending on whether they are more or less spaced; the columns A and B seeming slenderer than the columns D and C, even though they are equally thick* (82). The drawing represents two different intercolumniations over a gradient shaded background. Graphically, the drawing is more intuitive than geometric, and the shadows are not calculated (figure 1).

Perrault translated *air* by *l'air* & *le grand jour*, and then completed and corrected the daylight-idea given by Vitruvius. He commented:

If air here means light, as there is a great similitude, it seems that columns brought closer to each other, shall provoke an opposite effect to what is said here, that is to say that the closer they are, the slenderer they shall appear, because a column whose neighbors subtract the daylight that would otherwise illuminate its sides if they were further apart; is obscured on the right and left with two shadows that merge with the one behind and which reigns along the portico, which diminishes its apparent thickness, that would seem differently if its sides being illuminated were cutting more sharply the shade behind; as it is seen in Figure 1 of the table XVII where columns A B that are squeezed up seem more slender than columns CD, even though they all have the same thickness. We may then say that the true reason for this seemingly column-thickness diminution when they are distant from each other, is that they do not appear adequate to carry a long entablature; and also, that the necessity to thicken the columns as one may move them apart, is based on the fact that a heavy load requires something stronger to support it. (81)⁵

While Vitruvius thought that columns might be eaten away by the light, Perrault, on the contrary, accused the cast shadow: a similar mechanism could affect the columns' perceived solidity, and therefore would alarm the beholder on their weak capacity to bear the entablature's load. Shadow operates as a proportion-modifier and creates the illusion of a "lightness that destroys the harmony", as Le Camus de Mézières stated, since the column seems as slender as "a reed, incapable of supporting any weight; and this violates one of the most essential principles of all, namely the idea of solidity that every structure must have." (Le Camus de Mézières 1972, 85)

In expressing a differing opinion from that of Vitruvius, Perrault brought forth the viewpoint of his time, regarding the nature of ocular deception, and its being created more by shadows than by light. Shadow became a more powerful danger for proportion, especially during this century when the conditions of solidity were evolving.

3. SHADOWS IN THE DECORATIVE SYSTEM OF FRENCH ENLIGHTENMENT'S ARCHITECTS: LE CAMUS DE MEZIERES, BOULLÉE AND LEDOUX

3.1 EVOLUTION OF THE CONDITIONS OF SOLIDITY: BETWEEN CALCULATION AND SENSATION

The solidity of the architectural form was, during the French Enlightenment, battling between two positions that emerged from an increasing differentiation between architect's and engineer's practice. On one side stood Blondel and the verisimilitude of construction, on the other "revolutionary architects", (Kaufmann

1952) such as Boullée and Ledoux, who explored the notion of solidity through new architectural effects rendered with simple geometrical shapes. Calculation or sensation became the two main ways to achieve it.⁶ From Condillac's legacy for who sensation is at the origin of knowledge, to the lectures by Monge, Lagrange, and Laplace at *les Ecoles Normales*, where mathematical rationality triumphs, the rapports are not as dichotomous as they may seem, and one may simply not oppose calculation to sensation.

The engineer Riche de Prony, in his "Reflections on the organization of an academy that would aim at the perfecting and the teaching of construction" [*Réflexions sur l'organisation d'une académie qui aurait pour objet la perfection et l'enseignement de la construction*] stated that "the art of discussing and analyzing is not incompatible with the one of painting and stirring" (Quoted in Picon, 95)⁷ and suggested to add the study of Greek proportions, alongside the teaching of mechanics.

3.2 THE RISING APPRECIATION OF SHADOWS: BETWEEN GEOMETRY AND INTUITION

The question of shadows followed the very same dynamics, between sensation and calculation. On one hand, the shadow of architectural form was considered from a mathematical point of view. Shadow arose in architecture through descriptive geometry for which Dupain de Montesson, tactician, surveyor and engineer initiated in 1750 the tradition with the first edition of *The Science of Shadows* [*La Science des Ombres, par rapport au dessein. Ouvrage nécessaire à ceux qui veulent dessiner l'architecture civile & militaire, ou qui se destinent à la peinture*] the first french manual dedicated to the geometrical representation of shadows in architecture, a tradition pursued subsequently by Delagardette and L'Eveillé.⁸

The drawing convention of shadow places the light source with an angle of 45° on both horizontal and vertical plans. The final table of *La Science des ombres* is dedicated to "the effect of light on mixed bodies" (Dupain de Montesson 1786, 80).⁹ and examines the particular case of ornaments such as the base and its scotia, the column capital, the torso, and different moldings of the entablature (figure 2). To calculate shadow according to a theoretical sun position allows one to simulate a phenomenon that is in its nature ever-changing but predictable at a certain time. The theoretical moment chosen enables, by a geometrical report of points, to read the depth of the relief thanks to the length of its cast shadow. This latter then introduces in the orthographic drawing the third dimension.

On the other hand, and in a similar effort as the one made by the beholder who reads a shaded drawing

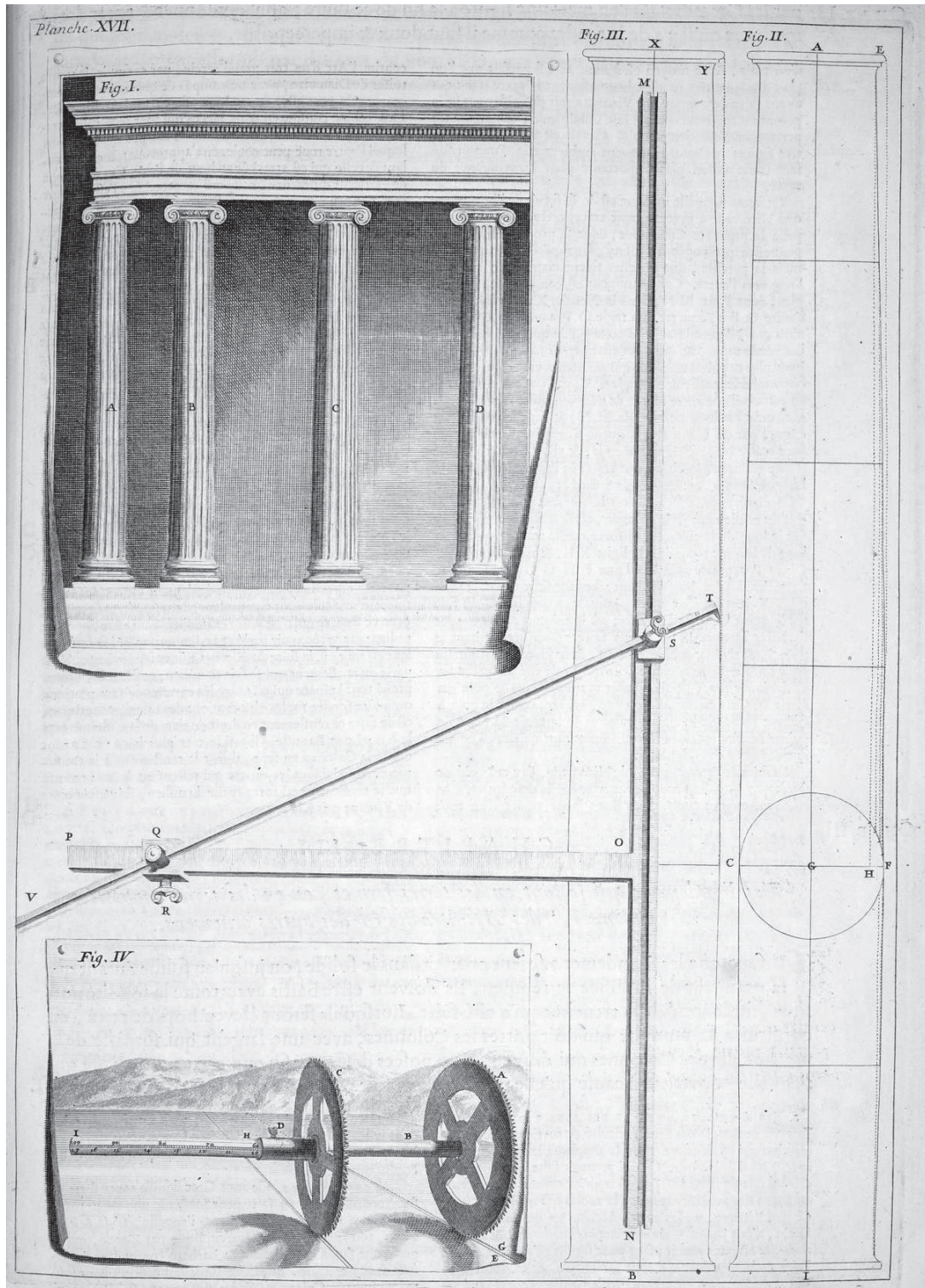


Figure 1: Demonstration of different effects of shadows on the perception of the thickness of columns. (Claude Perrault, *Les dix livres d'architecture de Vitruve*, table XVII, 1684)

to understand the relief, for sensualists like Condillac, the shadow represents the means by which one may recognize at first glance “figures, sizes, situations and distances” (Condillac 1792, 4)¹⁰, even though this knowledge requires the sense of touch at a preliminary stage of perception.

3.3 TOWARDS A DECORATION BY SHADOWS: PICTORIAL ORIGINS AND ARCHITECTURAL LIMITS

Whether it be related to a geometric approach or to a sensualist one, this type of shadow seems to result from the transition of a pictorial knowledge to an architectural knowledge. Undeniably, shadow is one of the painter’s favored tools. It is at the very origin of the discipline: Dibutade’s daughter invented painting while tracing the contours of her beloved’s cast shadow on a wall;¹¹ Da Vinci resolved the problem of perspective by analogy with the geometry of shadow.¹² Not only does shadow enhance the verisimilitude of a scene by giving the sensation of relief, but it also is a powerful tool for pictorial composition. From the Renaissance with Alberti, and more particularly from the second half of the seventeenth century in France, the challenge of treatises on painting was to measure and dose the quantity of light according to the quantity of dark on the canvas and their respective position. The term *chiaroscuro* [“clair-obscur”] entered at that time French painting theory, as well as, *group*, *masse of light and dark*, and *rest*, each of them abiding by the principle of *harmony*.

It is with an homage to Watelet that Le Camus de Mézières opened *Le Génie de l’Architecture*. Watelet was a painter and the most influential theoretician of his time although he did not make any major contribution to his discipline besides transmitting ideas developed during the previous century by Dufresnoy and his friend and translator De Piles.¹³ In Le Camus’ work, which aimed at an audience of architects, the author proposed to build an “analogy of the proportions of Architecture with our sensations” (Le Camus de Mézières 1972,

1). These sensations are seen as the result of the effects of architecture on the soul. It is in the collective effort of the three sisters,¹⁴ architecture, sculpture and painting that Le Camus recognized the potential for achievement of the greatest effects. The making of effects lay in the combination of basic elements such as “the whole, the masses, the proportions, the shadows, and the lights” (75). Shadows of protuberance, in which one may find ornaments, became the privileged place for an intersection between architecture, sculpture and painting. The artistic crossing of these lies in the common implementation of means, know-how and aesthetical intentions: architecture, in the sense that shadow is appointed as a tool dedicated to creating effects; sculpture, in the sense that it is the protuberant ornament that casts its shadow on the façade; and finally painting, in the sense that its methods are borrowed by the architect to compose their façades.

In Le Camus de Mézières’ words, shadow became a central topic in architectural composition. The author also considered himself as a forerunner in his will to integrate shadow into architectural theory.

“It is impossible to pay too much attention to the masses in a building, to their intended effect in elevation, and to the greater or lesser degree of light that may result; the shadows must temper the light, and the light must temper the shadows. In this principle, success resides; here alone true beauty is to be found; this can be considered and discussed, the truth will come to light, and the greatest benefits will ensue. This observation, we repeat, is essential. Even the most intelligent Architect can hope to succeed only by adapting his design to the exposure of the Sun to the principal parts of his building. Like the skillful Painter, he must learn to take advantage of light and shade, to control his tints, his shadings, his nuances, and to impart a true harmony to the whole. The general tone must be proper and fitting; he must have foreseen the effects and be as careful in considering all the parts as if he had to show a picture of them.” (95)

The injunction is double and seems at the edge of contradiction. The architect has to borrow from the painter his compositional tools regarding the disposition of light and shade on his façade-canvas. Yet, in contrast to the painter for whom light is chosen and unique, the architect ought to think his work stretching out in time and space and be prepared to see the well-thought shadows evolving, being distorted and running along the façade. While conceiving an architectural approach based upon the one used by painters, Le Camus overlapped on the façade two layers that could become antithetical. Indeed, it is difficult to handle at once the changing effects of shadows cast by strong reliefs and the necessity of expressing constant solidity.

The respect of proportions is no longer the only requirement that ornaments have to fulfill, because “it is light and shade that determine its success and

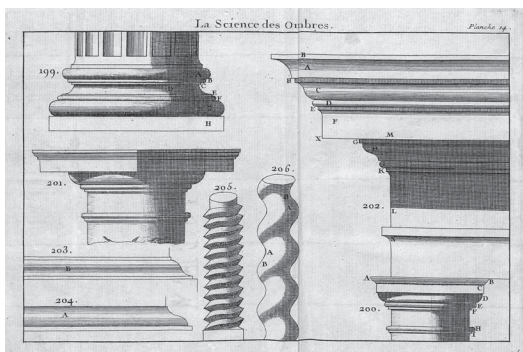


Figure 2: The effect of light on mixed bodies. (Dupain de Montesson, L.-C. La science des ombres... Nuremberg: Weigel, 1786)

contribute most to its character.” (100) The effect of smooth or sharp shadows should be the consequence of a certain disposition and depth given to ornaments.

“The true artist [...] will understand that if he wishes his building to set a calm and gentle scene, he must combine masses that do not differ too widely, he will see that they must have too much variety and relief and that the prevailing tone must be one of tranquility and majesty; the contrasts of light and shade must be well regulated, for any excess of either would be harmful. Nothing better conveys the character of mildness than shadows that become less dense as they grow longer.” (94)

Even though the definition of shadows only relies on the projection of ornaments and masses and not on their forms, edges or surfaces, Le Camus’s decorative recommendations lean on a utilitarian construction that one may appraise from the table of contents: characters and architectural effects are at the center of his theory and grounded on a fine programmatic dissection, since “each room must have its own particular character.” (88)

Le Camus was attached to the very notion of solidity, as we have seen earlier. Yet, he never proposed any technical means to solve the problem that shadows might present. He was instead much more concerned with the classification of its effects and with the promotion of pictorial tools in architecture.

Boullée and Ledoux abandoned the traditional models supported by Blondel and conceived buildings made of simple and pure geometrical shapes, with ornament freed from classical rules and a sensualist accent very similar to Le Camus’ discourse. Projections and their shadows are recognized as basic elements to the architectural forms. “What might one say of a monster that would have neither arms nor legs? Such would be the fate of Architecture were one to remove the only effects obtained through its main parts; well-combined projections, cast shadows [...]” (Ledoux 1804, 28).¹⁵ The architects pursued the painter’s example and Ledoux questioned: “You who wish to become an Architect, begin by being a painter: what variety will you find spread over the inactive surface of a wall, whose picturesque eloquence does not stir the apathetic multitude” (112).¹⁶ The façade again is conceived as a canvas on which the architect would dispose his shadows. Yet, Ledoux was very well aware of the variability of these effects and reminded of the inconstancy of the shadows cast by projections “under a moving star” (47).¹⁷ The description Ledoux made of the director’s house of the Arc-et-Senans Royal Saltworks is an occasion to assess a strong decorative will through the use of shadows, including those cast by the banded rustication of columns and pilasters whose recess between “squared and rounded courses [...] produce sharp shadows, and vivid effects ” (134).¹⁸ The need for strong effects made by such shadows is justified by the

distance of the beholder from the edifice, distance that blurs the details of its ornaments.¹⁹ Merging shadow into the decorative system cannot however be done at the expense of the “apparent solidity” that Ledoux opposed to an “actual solidity” (45).²⁰ Ornaments that present significant projections, like the cornice, or overhanging roof, produce shadows that may subtract “the seeming solidity that one desires” (119).²¹

CONCLUSION

Despite the fact that Vitruvius developed a discourse on shadow in his *gnomonic*, and that Alberti wrote both treatises on architecture and painting, the theorists never openly constructed a link between shadow, ornament and the appearance of solidity. In France, it is only during the eighteenth century that architecture began to consider the play of shadow on façades. It is also during this century when architecture had to face a radical change in its practice: with the emergence of engineering and therefore the questioning of the architect’s role, this latter had been sought in its relation to other visual arts. The result is that the very pictorial approach of decoration had to overlap the pictorial approach of solidity, creating thus vivid conflicts. This century may be seen as launching the subject matter, since the link between shadows, decoration and solidity found an unexpected development during the following century through the figures of Quatremère de Quincy, Viollet-le-Duc, or John Ruskin in England. These architects and critics not only underlined the problem of shadows on solidity, but they also formulated pragmatic methods to limit its impact and enhance its decorative qualities. The nineteenth century, triggered by the romanticism of shadow, is the century when architecture fully captured the theoretical question of its function in the decorative system and mastered it. Column, scotia and cornice became part of a wider range of ornamental shapes which, according to their edges, geometry and reflective properties, were conceived as devices and means to design decoration by shadows.

ACKNOWLEDGEMENTS

I thank the Stiftung Bibliothek Werner Oechslin and the Heidelberg University Library for providing figures 1 and 2, respectively. I would also like to thank Korinna Zinovia Weber, Zena Barton and Jérémie Trazic for their time and effort reviewing this paper.

ENDNOTES

- 1 "Account should be taken of the seasons, so that rooms intended for summer use should not be the same as those intended for use in winter, in that they should have different sizes and locations; summer rooms should be more open, nor is it amiss if winter ones are more closed in; summer ones require shade and draught, while winter ones need sunlight." (Alberti 1988, I-9, 23); "...the infill and the twin skins or shells on either side, one to keep the wind and sun out, the other to protect the area within." (III-6, 69)
- 2 "The window openings of a temple should have modest dimensions and should be placed high up, where they have a view of nothing but the sky, which will not divert the minds of celebrant or supplicant from divine matters. The awe that is naturally generated by darkness encourages a sense of veneration in the mind; and there is always some austerity about majesty. What is more, the flame, which should burn in a temple, and which is the most divine ornament of religious worship, looks faint in too much light." (VII-12, 223)
- 3 This warning relates to the preference for square columns under arcades instead of round ones, a structural argument unexpectedly placed in the part dedicated to ornaments, "For arched colonnades quadrangular columns are required, the work would be defective with round columns, since the springing of the arches could not be fully supported by the solid of the column, and whatever lay in plan beyond the circle contained by the square would rest on nothing but thin air." (VII-15, 236); a similar warning may be found in the third book, "Give your wall the firmest possible base; the top must be centered along the vertical and must correspond exactly to the bottom" (III-11, 78)
- 4 "Le mot Grec Scotos signifie obscurité. La partie qui est enfoncée dans la base est appelée Scotie, parce qu'elle est la plus ombragée". Claude Perrault, *Les Dix Livres d'Architecture de Vitruve* (Paris: Jean Baptiste Coignard, 1684), 90. Translation by the author.
- 5 "Si l'air signifie icy la lumiere, comme il y a une grande apparence, il semble que les Colonnes serrées les unes contre les autres doivent faire un effet contraire à ce qui est dit icy, c'est-à-dire que plus elles sont pressées, plus elles doivent paroître menuës, parce qu'une Colonne à qui ses voisines dérobent le jour qui illumineroit ses costez, si elles estoient plus éloignées, est obscurcie à droit & à gauche de deux ombrages qui se confondent avec celui qui est derriere & qui regne le long du Portique, ce qui diminue l'apparence de sa grosseur, qui paroistroit tout autrement, si ses costez estant illuminez coupoient plus distinctement cette ombre qui est derriere; comme il se voit dans la I. Figure de la Planche XVII. où les Colonnes A B, qui sont serrées l'une contre l'autre paroissent plus menuës que les Colonnes CD, quoy qu'elles soient toutes d'une mesme grosseur. On peut donc dire que la veritable raison de cette apparence de la diminution de la grosseur des Colonnes quand elles sont éloignées, est qu'il semble qu'elles ne sont pas suffisantes pour porter un long entablement; & qu'aussi le necessité de grossir les Colonnes à mesure qu'on les éloigne l'une de l'autre, est fondée sur ce que la plus grande charge qui est soutenüe, demande quelque chose de plus fort qui la soustienne." Perrault, *Les Dix Livres d'Architecture de Vitruve*, 81. Translation and emphasis by the author.
- 6 Antoine Picon, "Solidité et construction, quelques aspects de la pensée constructive des Lumières", *L'Idée Constructive en Architecture: Actes du Colloque Tenu à Grenoble au 28 au 30 Novembre 1984*, ed. Xavier Malverti (Paris: Picard, 1987), 95.
- 7 "l'art de discuter et d'analyser n'est point incompatible avec celui de peindre et d'émouvoir". Gaspard Riche de Prony, *Réflexions sur l'Organisation d'une Académie qui aurait pour Objet la Perfection et l'Enseignement de la Construction*, Manuscrit E.N.P.C, MS1056. Quoted in Picon, "Solidité et construction, quelques aspects de la pensée constructive des Lumières", 95. Translation by the author.
- 8 Claude-Mathieu Delagardette, *Leçons Élémentaires des Ombres dans l'Architecture, faisant suite aux Règles des Cinq Ordres de Vignole...* (Paris: Dallenne, 1851); Charles Stanislas L'Eveillè, *Etudes d'ombres à l'usage des écoles d'architecture*, (Paris: Treuttel et Wurtz, 1812).
- 9 "l'effet du jour sur les corps mixtes". Dupain de Montesson, *La Science des Ombres*, 80.
- 10 "des figures, des grandeurs, des situations et des distances". Etienne Bonnot de Condillac, *Le Traité des Sensations* (Parme, 1792), 4.
- 11 Pliny the Elder, *Naturalis Historia*, XXXV-15 and 43
- 12 Thomas Da Costa Kaufmann, "The perspective of shadows: the history of the theory of shadow projection", *Journal of the Warburg and Courtauld Institutes* 38 (1975), 258-87, <https://www.jstor.org/stable/750956>.
- 13 Charles-Alphonse Dufresnoy, *De Arte Graphica* (Paris: L'Anglois, 1668); Roger De Piles, *Cours de Peinture* (Paris: Etienne, 1708).
- 14 The eighteenth French century was keen on calling arts "sisters" as if they were ancient muses.
- 15 "Que diroit-on d'un monstre qui n'aurait ni bras ni jambes? C'est ce que deviendrait l'Architecture dont on supprime les seuls effets que l'on puisse tirer des corps; des saillies bien combinées, des ombres portées [...]". Claude-Nicolas Ledoux, *L'Architecture considérée sous le Rapport de l'Art, des Mœurs et de la Législation* (Paris: Ledoux, 1804), 28. Translation by the author.
- 16 "Vous qui voulez devenir Architecte, commencez par être peintre: que de variétés vous trouverez répandues sur la surface inactive d'un mur, dont la pittoresque éloquence ne remue pas la multitude apathique". Ledoux, *L'Architecture*, 112. Translation by the author.
- 17 "toujours assujetties aux emprunts forcés d'un astre mobile". Ledoux, *L'Architecture*, 47. Translation by the author.
- 18 "les assises carrées et rondes [...] reculent et produisent des ombres tranchantes, des effets piquants; ces combinaisons de l'art changent les contrastes à mesure que le soleil s'étend dans sa course méthodique". Ledoux, *L'Architecture*, 134. Translation by the author.
- 19 "Projections cast sharp shadows; it is a mean to substitute strength to the weakness produced by distance [...] This is the power of forms that reign over distances." ["Les saillies produisent des ombres piquantes; c'est un moyen de substituer des forces à la faiblesse produite par l'éloignement. [...] Tel est le pouvoir des formes qui commandent aux distances"]. Ledoux, *L'Architecture*, 135. Translation by the author.

20 "solidité apparente" and "solidité réelle". Ledoux, *L'Architecture*, 45. Translation by the author.

21 "La saillie du toit que vous voyez et qui soustrait dans son développement l'apparente solidité que l'on désire, doit paroître hazardée". Ledoux, *L'Architecture*, 119. Translation by the author.

REFERENCES

- Alberti, L. B. 1988. *On the Art of Building*. Translated by Joseph Ryckwert, Neil Leach and Robert Tavernor. Cambridge: The MIT Press.
- Alberti, L. B. 2011. *On Painting*. Translated by Rocco Sinisgalli. New York: Cambridge University Press.
- Arnheim, R. 1974. *Art and Visual Perception: A Psychology of the Creative Eye*. Berkeley: University of California Press.
- Cache B. 2019. *L'Encyclopédie Vitruvienne Aujourd'hui?* Lausanne: Presses Polytechniques et Universitaires Romandes.
- Condillac E. de B. 1792. *Le Traité des Sensations*. Parme: s.n.
- Da Costa Kaufmann, T. 1975. "The Perspective of Shadows: The History of the Theory of Shadow Projection." *Journal of the Warburg and Courtauld Institutes* 38 (1975): 258-87. <https://www.jstor.org/stable/750956>.
- Delagardette C. M. 1851. *Leçons Élémentaires des Ombres dans l'Architecture, Faisant Suite aux Règles des Cinq Ordres de Vignole*. Paris: Dallenne.
- De Piles, R. 1708. *Cours de Peinture*. Paris: Etienne.
- Dufresnoy, C.A. 1668. *De Arte Graphica*. Paris: L'Anglois.
- Dupain de Montesson, L.C. 1786. *La Science des Ombres, par Rapport au Dessin. Ouvrage Nécessaire à Ceux qui Veulent Dessiner l'Architecture Civile & Militaire, ou qui se Destinent à la Peinture*. Paris: Cellot.
- Kaufmann, E. 1952. *Three Revolutionary Architects, Boullée, Ledoux And Lequeu*. Philadelphia: American Philosophical Society.
- L'Eveillé C.S. 1812. *Etudes d'Ombres à l'Usage des Écoles d'Architecture*. Paris: Treuttel et Wurtz.
- Le Camus de Mézières, N. 1972. *Le Génie de l'Architecture ou l'Analogie de Cet Art avec Nos Sensations*. Translated by David Britt. Geneva: Minkoff Reprint.
- Ledoux, C.N. 1804. *L'Architecture Considérée sous le Rapport de l'Art, des Mœurs et de la Legislation*. Paris: Ledoux.
- Payne, A. 1999. *The Architectural Treatise in the Italian Renaissance: Architectural Invention, Ornament, and Literary Culture*. New York: Cambridge University Press.
- Perrault, C. 1684. *Les Dix Livres d'Architecture de Vitruve: Corrigez et Traduits Nouvellement en François, avec des Notes et des Figures*. Paris: Jean Baptiste Coignard.
- Picon, A. 1987. "Solidité et Construction, quelques Aspects de la Pensée Constructive des Lumières". In *L'idée Constructive en Architecture: Actes du Colloque Tenu à Grenoble au 28 au 30 Novembre 1984*, edited by Xavier Malverti. Paris: Picard, 1987.
- Pliny the Elder. 1961. *Natural History with English Translation in Ten Volumes*. Translated by Harris Rackham. Cambridge: Harvard University Press.
- Reed, A. 1990. "Signifying Shadows". In *Architecture and Shadow*, edited by David Murray, 12-25. Philadelphia: University of Pennsylvania.
- Vitruvius, M.P. 1960. *De Architectura*. Translated by Morris Hicky Morgan. New York: Dover Publications.

SHAPE-CHANGING ARCHITECTURAL SYSTEMS: A Bottom-up and Top-down Approach for Developing Responsive Building Skins

Elena Vazquez
Penn State University

Abstract: In recent years, there has been an increasing interest in shape-changing smart materials in architectural research and practice. Research into responsive building skins with shape-changing materials has argued that the advantage of such systems relies on their potential for improved performance of buildings. However, few studies have proposed methods for developing responsive skins using shape-changing materials with the target of optimizing environmental performance. This paper discusses the methodological approach of a doctoral research agenda that aims to create a framework for developing a responsive shading system using shape-changing materials with the target of optimizing environmental performance. The methodology has two complementary approaches: a bottom-up study that deals with the development of shape-changing prototypes and top-down research that models the overall configuration of the responsive skin system. The paper discusses the two complementary approaches in terms of a case study.

Keywords: responsive skin, shape-changing materials, research methods, smart materials

INTRODUCTION

In recent years, there has been an increasing interest in smart materials in architectural research and practice. The development of novel materials in material science, chemistry, and other related fields has provided an entirely new material palette for designers (Addington and Schodek 2012). These include smart materials, from thermochromic materials that change visual appearance due to temperature changes to piezoelectric materials that present an electric response when mechanical stress is applied. Among these materials, shape-changing materials are characterized by presenting a strain that leads to a material transformation in response to a stimulus (i.e., water, heat, electricity). While there is an increasing number of studies that explore the development of architectural elements using these shape-changing materials, there has been little discussion of the strategies designers can use for efficiently incorporating these materials into architectural design.

On the other hand, in the current context of increasing environmental concern, a considerable amount of research has been directed at developing more efficient architectural skins. In fact, the envelope of a building is known to have a significant impact on environmental performance and thus accounts for a large portion of the total energy consumption of buildings (Echenagucia et al. 2015). Drawing inspiration from nature, a bio-inspired approach to research into building envelope design has adopted the term architectural skin (Velikov and Thun 2013) to name the barrier between inside and outside responsible

for protecting, exchanging, and harvesting functions. Innovative architectural skin systems have started to emerge in the past decades using smart materials, and more specifically, shape-changing materials. Research into developing responsive architectural skins with shape-changing materials has argued that the advantage of such materials relies on the improved performance of buildings. However, few studies have proposed methods for developing responsive skins using shape-changing materials with the target of improving environmental performance. The question is, then;

1. *How can we develop a responsive skin using shape-changing materials with their inherent material properties and limitations?*
2. *How can environmental performance simulation inform the design of such a responsive skin system?*

These two research questions are causally interlinked and cannot be solved linearly. The work presented in this paper forms part of an ongoing doctoral research agenda aimed at developing computationally-enabled design and fabrication protocols for responsive skin systems using shape-changing materials that target improved environmental performance in buildings. This paper describes the overall methodological approach selected to address the two research questions mentioned above. The methodology has two complementary approaches: a bottom-up study that deals with the development of shape-changing skin prototypes, and a top-down study that models and proposes the overall configuration

of a responsive skin system based on performance metrics. We show examples of the two complementary approaches by tracing the development of a responsive skin system fabricated by 3D printing with a hydro-active wood filament, as a case study.

The first section of this paper provides a brief overview of shape-changing smart materials and on the use of shape-changing materials for improved environmental performance. The next section presents the overall framework, describing the methodological approach proposed, and examples of implementing the framework with the case study of developing a responsive skin by 3D printing with hydro-active wood. Finally, the paper presents a discussion on the expected outcomes of this research.

1. BACKGROUND

The two research questions presented in the introduction require two different bodies of knowledge as the theoretical foundation of this research. The first relates to the bottom-up development of designs, based on a material-centered exploration. This research is concerned with proposing novel designs with materials typically developed outside the field. Therefore, these materials need to be experimented with to account for their properties, constraints, and affordances. The second group of studies relates to the use of shape-changing smart materials in the construction of building envelopes that optimize environmental performance. This section provides an overview of these two bodies of literature that frame this research.

1.1. SHAPE-CHANGING MATERIALS FOR IMPROVED ENVIRONMENTAL PERFORMANCE

Smart materials have long been in the research agenda of material scientists and engineers but have only recently begun to permeate design practice. Shape-changing materials when affected by a stimulus -water, temperature, or other- present a strain that leads to shape change. A recent review (Vazquez, Randall, and Duarte 2019) has identified (hygroscopic) wood and Shape Memory Alloys as the two most common materials used for their shape-changing properties. The review has also indicated typical design and manufacturing patterns, extracted from a group of 44 studies (from 2007 to 2019). The extracted patterns indicate typical design solutions to developing responsive skin system with shape-changing materials, for instance, the combination with static materials or the use of shape-changing materials as the skin or the actuator. The patterns also capture common manufacturing strategies across the studies, showing how researchers have constructed shape-changing actuators. Furthermore, the review

highlighted the lack of studies that incorporate building performance simulations to shape the design of such responsive skins. Remarkably, one of the main arguments for the incorporation of such materials into architectural practice relies on the promise of improved environmental performance. Nevertheless, this area remains widely unexplored.

There are several types of skin or envelope systems one could select to enhance environmental performance in buildings. Figure 1 illustrates three different approaches. Perhaps the most well-known relies on optimizing a skin system by selecting the 'overall best' design solution. This approach can be seen in the work by (Vazquez, Poerschke, and Duarte 2020), where an optimal brick configuration is selected for a shading masonry screen wall, considering yearly values of daylight and energy performance. A drawback of this approach is that the design optimization occurs before construction; therefore, it does not account for fluctuating environmental conditions throughout the year or even varying conditions on the environment—such as new surrounding buildings—that change the exposure of buildings to the sun. This first type of skin solution for improved environmental performance is a *static system*. The second approach relies on the use of mechanical systems to construct responsive skins that adjust their configuration to respond to shifting environmental conditions. With this approach, the skin can adopt the most favorable configuration according to the environmental conditions, thereby improving environmental performance. This second type of system can be seen in the responsive skylight by Castro Henriques (2012 Engineering and Construction (AEC)). The high maintenance and material cost of such mechanical systems is perhaps the most significant disadvantage of these types of envelopes. This second approach can be characterized as a *dynamic system*. There is a third approach that is enabled by shape-changing smart materials, a responsive system where these materials replace expensive systems and are designed to adjust their configuration in response to changes in the environment.

This research targets the creation of a shape-changing system that can improve environmental performance in buildings, aligned with the third approach described as a responsive system. The ability to dynamically adjust to shifting environmental conditions without costly mechanical systems by using shape-changing smart materials is, without a doubt, a promising area of inquiry. The embedded sensor and actuation technologies of shape-changing materials enables designers and researchers to envision novel systems that can help improve the environmental performance of buildings.



Figure 1: Different types of skin systems for enhancing environmental performance in buildings. (Author 2020)

1.2. MATERIAL-CENTERED EXPLORATIONS

On the other hand, this research also seeks to find ways to achieve optimal design configurations using shape-changing materials, understanding their inherent material properties and limitations. Designing with shape-changing materials presents several challenges since they are inherently dynamic, which challenges one to design with the 4th dimension of time (Kennedy 2012; Vazquez and Duarte 2019). Another critical issue of designing with smart materials is how to combine them with existing building systems, and how to understand their affordances and limitations beyond mere replacement of current building structures (Kretzer 2014). Consequently, the development of responsive architectural skins using shape-changing material is highly experimental and requires iterative cycles of design, fabrication, and testing. This research adopts an experimental model of inquiry, where the development of prototypes and subsequent testing informs the construction of a design system.

This research is aligned with the emergence, in digital design culture, of a material-centered approach, which favors experimental models of research. Ahlquist et al. 2013, for instance, argues that a framework for computational thinking is critical for enabling research into a material system where there is a sequence of experimentations in increasing levels of complexity. The framework proposed by the author seeks to integrate material properties as design generators, where digital techniques enhance the integration of form and structure within the logic of manufacturing technologies (R. Oxman 2012). The model opposes the dominant epistemological frameworks in design that usually rely on final products rather than processes of material formation, as described in work by (Gürsoy and Özkar 2015). By adopting such an approach, the goal is to develop systems where the properties of shape-changing materials are not a foreground of

their application (Addington 2010) or 'patched atop' existing technologies (N. Oxman 2010), but instead, their properties give form to efficient and responsive systems.

Research into shape-changing materials -and new materials, in general, has already adopted such experimental models of inquiry. The presence of an iterative cycle of development and testing can be traced in the work of several studies on shape-changing materials in architecture. For instance, Yoon (2019) argues that he conducts his research into Shape Memory Polymers for thermal-responsive facades through intuitively proposing design solutions and verifying them through fabrication and digital simulation. Similarly, Khoo et al. (2011) propose three design experiments in developing morphing skins with Shape Memory Alloys and develop prototypes to test and suggest new architectural design ideas. The introduction of shape-changing materials in architectural design is at its early stages. Therefore, most studies adopt an experimental approach going through incremental cycles where computational tools and methods aid the process. Furthermore, the dynamic behavior of the shape-changing materials is usually not known in advance to researchers, since in most cases, these materials are constructed -for example, through bi-layers or 3D printing. Therefore, a systematic and experimental approach helps understand the embedded material intelligence of these materials to incorporate them into responsive systems.

2. RESEARCH APPROACH

2.1. THE CASE STUDY: DEVELOPING A RESPONSIVE 3D PRINTED HYGROSCOPIC SKIN

This research adopts the form of a case study detailed in this section. While this paper focuses mainly on presenting the research methods, a brief background on the problem and the current state is necessary to contextualize the discussion. The case study proposed

is the development of a responsive architectural skin fabricated through 3D printing with a hygroscopic wood-based filament, that could potentially improve daylight conditions indoors. The two research questions refer to, on one hand, proposing a design system for improved environmental performance, and on the other, developing such a system using a shape-changing material with its inherent properties and limitations. To explore the potential design configurations with the shape-changing material, one must adopt the bottom-up approach. To propose and optimize such configurations, one must adopt a top-down approach. The methods section details these parallel and complementary courses of action.

As mentioned before, this research started with a systematic review of the literature, which identified typical design and manufacturing patterns among the body of literature on shape-changing materials used for responsive building envelopes. The review also identified the need for developing responsive building skins, taking into consideration environmental performance factors. Following the review, the first explorations in this research project aimed to study the constraints and affordances of the material by developing initial manufacturing digital protocols for 3D printing and, thereafter, characterizing its hydro-active behavior. Relevant references of this study were the 3D printed responsive systems by Correa et al. (2015) and Correa and Menges (2017). In the studies, the authors presented methods for designing hydro-active wood structures by 3D printing, controlling the alignment of wood fibers through toolpath design.

Building upon this existing body of work, the first set of outcomes of our experimental study was formalized into rules in (Vazquez, Gürsoy, and Duarte 2020). The rules depict the lessons learned from toolpath design, shape-change and how to capture it, and design principles for shape-changing kirigami geometries. The next step of this research is to speculate on the form of a large-scale skin system and construct a full-size physical model, to assess the material limitations and deal with scalability issues.

2.2. THE RESEARCH FRAMEWORK

This section details the methodological approach adopted in this doctoral research aimed at developing a responsive skin using shape-changing materials for improved environmental performance in buildings. The first section describes the overall framework for addressing the research question in two complementary approaches. The second section moves on to describing the specific model utilized for conducting the bottom-up section of the research. The methods and approaches are described in terms of the case study for developing

a responsive skin system by 3D printing with a hydro-active wood filament.

This research is conducted in two different and complementary approaches. The general methodology proposed to address these two research questions is illustrated in figure 2. As mentioned before, there are two complementary approaches involved. (1) A bottom-up approach that is concerned with prototyping the testing manufacturing strategies for a shape-changing system and (2) a top-down approach that deals with defining the overall geometry of the responsive skin system, focused on improved daylight performance. The two types of research are developed in iterative cycles of development and testing, going from manufacturing to the overall design, and vice versa. The cycle cannot be linear because novel design possibilities emerge from exploring and thinking with the material. At the same time, developing a design system for the overall configuration helps inform material explorations at a smaller scale, and provides parameters (shape, size) to the smaller scale.

The graphic also exemplifies what kind of studies are developed on each scale. In the smaller-scale work of the bottom-up studies, the research addresses the development of manufacturing strategies. The work conducted in this approach is aimed at formalizing strategies for embedding and programming responsiveness through manufacturing processes in this research by 3D printing. In the case study, these strategies refer to, for instance, defining toolpath configurations, studying how to construct bi-layered systems with differential swelling. Similarly, studies at the micro-scale of toolpath design are combined with studies at the mesoscale of geometrical configurations. In the case study, for instance, we studied how kirigami geometries deform when a stress is applied and see if we could replicate those transformations with toolpath design. To achieve this, we divided complex kirigami geometries into bending with opposite directions (concave and convex curvatures).

At the larger scale of the top-down approach, there is an interest in thinking about what could be suitable design configurations for shape-changing skins. This approach is, in a sense, more speculative. Nevertheless, it informs the bottom-up explorations by providing a goal and a direction to the studies. At this scale, digital simulation methods also inform the process by providing feedback on the desired performance of the skin systems. Namely, rough and early performance analysis can help inform the definition of initial configurations for the responsive system. Figure 3 shows a parametric definition of a responsive façade using kirigami geometries as the basic shape-changing module.

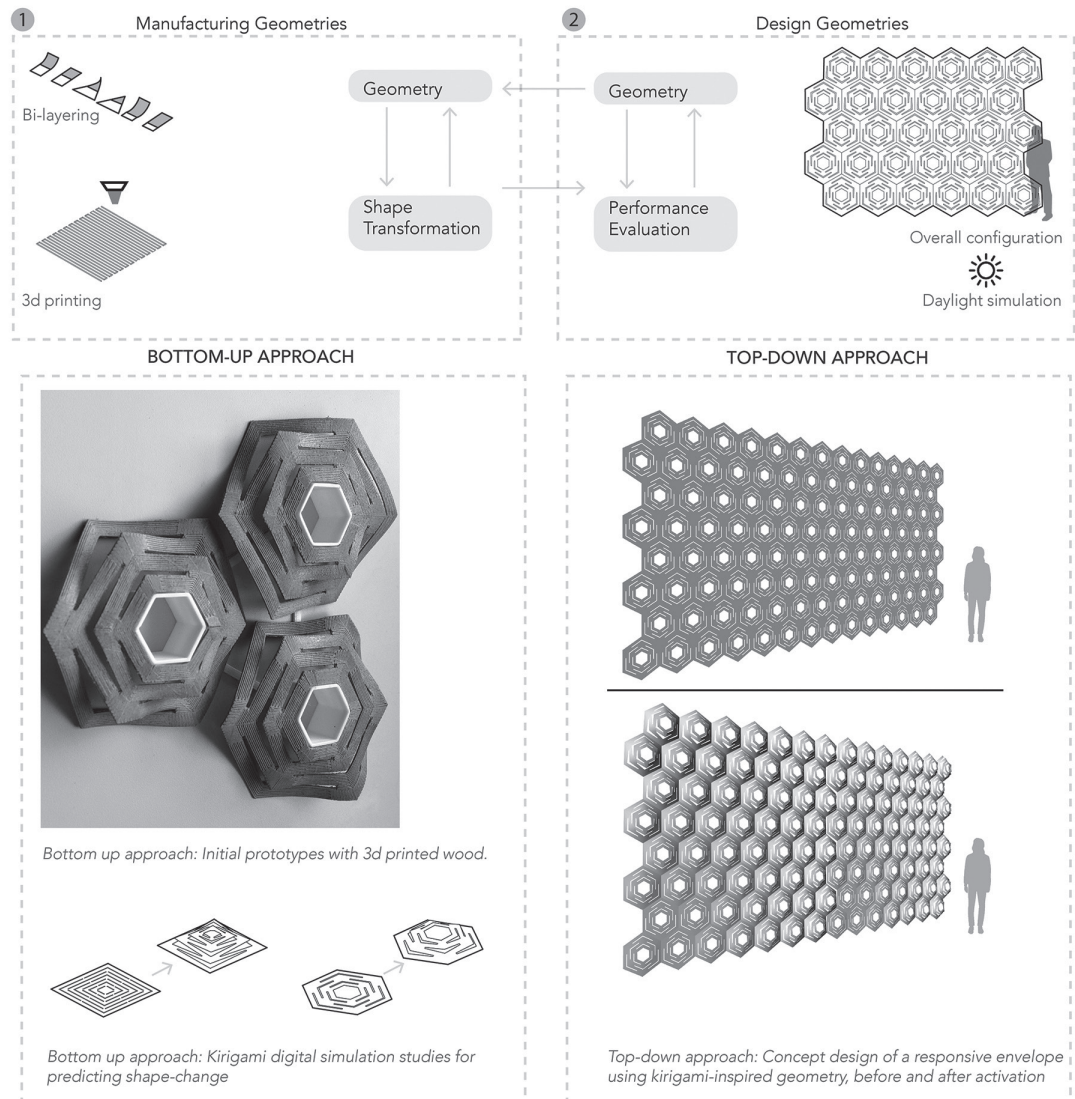


Figure 2: The general research framework. (Author 2019)

On the other hand, due to the lack of practical methodologies for material-centered explorations, we defined a model to guide this bottom-up iterative cycle of development and testing. Figure 3 illustrates the experimental model adopted of development and testing with shape-changing materials adapted from (Vazquez, Gürsoy, and Duarte 2020). The process begins by defining a framework for material exploration, which identifies the material/process/design/actuation variables that define the prototypes. For instance, when 3D printing responsive hygroscopic materials with wood-based filaments, the framework includes four types of variables. One, which filament is used (material variables), two, what printer and settings will be used to fabricate the responsive structures (process

variables), three what geometric configurations will the printed parts have (design variables), and four, what are the actuation conditions (activation variables) to be tested—for instance, relative humidity %. The next step is to perform a material exploration by systematically changing one variable at a time, to assess which settings perform best for the design purposes. Finally, the findings of this exploration are formalized through rules, computer algorithms, text descriptions, design patterns, or others. These findings also inform the next cycles of the process. The cycle of development and testing is a cycle of abstraction and materialization. For a more detailed explanation of the model for bottom-up explorations, readers can refer to (Vazquez, Gürsoy, and Duarte 2020)

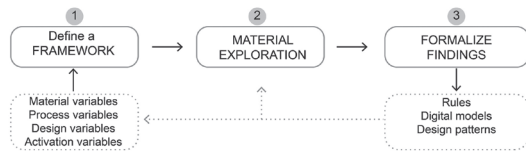


Figure 3: The model for bottom-up explorations. (E. Vazquez, Gürsoy, and Duarte 2019)

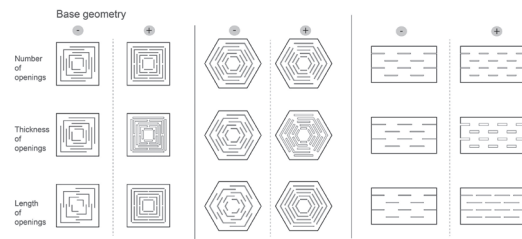


Figure 4: A design matrix for possible kirigami geometrical configurations. (Author 2019)

The initial framework for material-centered explorations can be based on a single type of variable, such as design variables. In the case study of 3D printing with a responsive wood filament, we were concerned with exploring the use of kirigami-inspired geometries for amplifying the shape-transformation of the prototypes. Consequently, after an initial testing in which we defined appropriate printing settings, we moved on to develop a second set of explorations based on a framework that considered mostly design variables. Therefore, we defined a design matrix for possible geometric configurations selecting different design variables that define such geometries. Figure 4 depicts the matrix developed that includes design variables such as number of openings, thickness of openings, and length of openings. From this matrix, we selected some geometries, and performed a material exploration to see how the different design variables conditioned the shape-changing response of the prototypes to humidity.

2.3. EXPECTED OUTCOMES

Having described the research framework, this section describes the expected outcomes of this research. Figure 5 depicts the general workflow of this study. The theoretical background, together with the extracted design and fabrication patterns done with the review, form the starting point of this research. The case study of developing a shape-changing architectural skin is done in increasing levels of complexity, through bottom-up and top-down studies as described in the previous section of this paper. The two complementary studies are developed through cycles of abstraction and materialization, where we go from digital-abstract

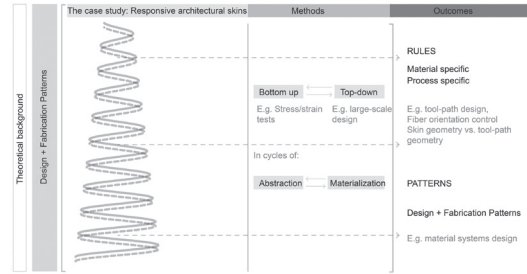


Figure 5: Research workflow. (Author 2019)

representations to materializing them. Finally, the two types of outcomes: rules and patterns, complete the process. These rules and patterns are intended to inform future research into designing and fabricating shape-changing architectural skins.

The outcomes of this research can be defined in terms of two levels. The first level is a series of rules that describe the interrelationship between material geometry, properties, and shape-changing behavior. These rules formalize material behavior and provide useful insights for the future development of responsive systems. For the most part, these rules are process-specific or material-specific. For instance, a set of rules defines the toolpath design, and a set of rules describes the shape-transformation. The theoretical support for the development of such rules will rely heavily on the shape grammar formalism. The grammar formalism is used to describe the material processes of making. Examples of this type of outcomes appear in (Vazquez, Gürsoy, and Duarte 2020), where we present rules for toolpath definition, rules for shape-change, and rules for defining kirigami geometries. While in some cases, these types of rules could be applied to other materials, this category of research outcomes is thought to be more process-specific and material-specific, since they do not have the flexibility attributed to the second type of research outcomes, patterns.

The second type of outcome is patterns. Patterns are understood in this context as "a solution to a problem in a recurring context" (Alexander 1977). In design science literature, patterns have been identified as more flexible and generalizable than rules that describe a technique for solving a class or type of problem (Vaishnavi and Kuechler 2015). Patterns also are defined as a "formalized way of recording experience" (Vaishnavi and Kuechler 2015, 2). In the context of this research, design patterns will describe generalizable techniques for designing shape-changing skin systems. Recall that one of the first steps of this research was to conduct an extensive literature review, where different design and fabrication patterns were extracted from the body of research into responsive

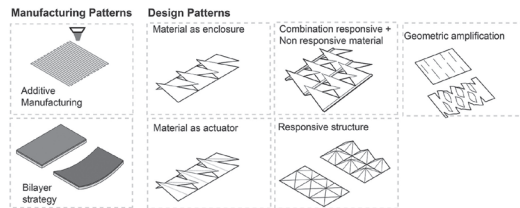


Figure 6: A summary of design and manufacturing patterns. (Author 2019)

skins -a summary of them illustrated in figure 6. This first set of patterns inform this study in framing the existing alternatives for shape-changing materials and design solutions for skin systems. The outcomes of this research will also be formalized as patterns. These will be both graphics responding to our visual culture as architects and designers and in text. The goal is that such patterns will be flexible enough to inform research into designing dynamic architectures in general, and skin systems with different materials in particular.

An example of a design pattern that already emerged from this research are strategies for using kirigami geometries combined with 3D printing to develop shape-changing modules that can be used in a responsive architectural skin. Figure 7 summarizes the proposed strategy for toolpath definition of a kirigami-inspired responsive system. The process starts with defining the main kirigami geometry, which can be selected from the design matrix shown in figure 4. A second step is to study the actuation target through paper mockups or digital simulation. This study would allow us to characterize the shape-changing transformation, and divide the surface as per bending type. The process finishes with the definition of toolpath with corresponding active layers that swell perpendicular to the longitudinal direction of the area, and constraint layers, printed parallel to the long side of the area.

In summary, the outcome of this research will be formalized using rules and patterns. Rules are generally considered stricter and, therefore, will be mostly material-process-fabrication specific. On the other hand, patterns are more flexible and therefore complement and enhance the rules. These patterns will refer to design and manufacturing strategies and will be formalized visually and through descriptions. These patterns are intended to inform research using other shape-changing materials.

CONCLUSION

Shape-changing materials have the potential of conforming truly responsive environments that adjust their configuration according to the surrounding

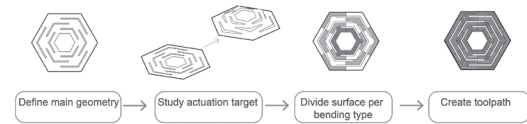


Figure 7: Proposed strategy for toolpath definition of shape-changing kirigami prototypes. Author 2019)

conditions. The increasing development of novel materials has allowed us, architects, to envision such spaces. The research presented is aligned with a research agenda intended at developing an efficient and responsive architectural skin system. This paper discusses the methodological approach adopted in a doctoral research agenda aimed at proposing methods for developing responsive skins using shape-changing materials with the target of optimizing environmental performance.

The methods discussed include two complementary approaches: a bottom-up strategy that aims to formalize fabrication strategies for achieving desirable design configurations and a top-down strategy that is concerned with studying and proposing an overall skin configuration for dynamically improving environmental performance. This research is conducted through iterative cycles of development and testing, jumping in between these two scales, where the findings of one scale inform the other and vice versa. Discussing examples of these two approaches, this article offers a reflective account of methods for design research in the new area of shape-changing materials.

This paper also discussed the expected outcomes of this study and its significance in the context of shape-changing architectural systems. Research into the potentials of shape-changing materials in architecture and design fields is in its early stages, being largely speculative yet visionary. Nevertheless, it is essential to formalize the design strategies for incorporating such materials into architectural elements, since such materials are inherently dynamic and conceptually different than traditional materials in architecture. These strategies go from how to synthesize material behavior to how to give them shape with digital fabrication methods. The outcomes of this research—defined as rules and patterns—intend to contribute to the discussion of how to incorporate shape-changing materials into design and research.

REFERENCES

- Addington, Michelle. 2010. "Magic or Material." *Perspecta* 42: 199–204.
- Addington, Michelle, and Daniel Schodek. 2012. *Smart Materials and Technologies in Architecture: For the Architecture and Design Professions*. Oxford: Routledge.
- Ahlquist, Sean, Geoff Thün, Catie Newell, and Kathy Velikov. 2013. "Toward a Pedagogy of Material Systems Research Toward a Pedagogy of Material Systems Research." In *TxA Interactive*, 22–33.
- Alexander, Christopher. 1977. *A Pattern Language: Towns, Buildings, Construction*. New York: Oxford University Press.
- Castro Henriques, Gonalo. 2012. "TetraScript: A Responsive Pavilion, from Generative Design to Automation." *International Journal of Architectural Computing* 10, no. 1: 87–104. <https://doi.org/10.1260/1478-0771.10.1.87>.
- Correa, David. 2017. "Fused Filament Fabrication for Multi-Kinematic-State Climate-Responsive Aperture." In *Fabricate 2017*, by Achim Menges, Bob Sheil, Ruari Glynn and Marilena Skavara, 190–95. London: UCL Press.
- Correa, David, Athina Papadopoulou, Christophe Guberan, Nynika Jhaveri, Steffen Reichert, Achim Menges, and Skylar Tibbits. 2015. "3D-Printed Wood: Programming Hygroscopic Material Transformations." *3D Printing and Additive Manufacturing* 2, no.3: 106–16. <https://doi.org/10.1089/3dp.2015.0022>.
- Gürsoy, Benay, and Mine Özkaz. 2015. "Visualizing Making: Shapes, Materials, and Actions." *Design Studies* 41, Part A (November): 29–50. <https://doi.org/10.1016/j.destud.2015.08.007>.
- Kennedy, Sheila. 2012. "Responsive Materials." In *Material Design - Informing Architecture by Materiality*, edited by Schröpfer T, 118–31. Basel: Birkhauser.
- Khoo, Chin Koi, Flora Salim, and Jane Burry. 2011. "Morphing Skins with Elastic Modular Systems Designing Architectural Morphing Skins With." *International Journal of Architectural Computing* 09, no.4: 397–419. <https://doi.org/10.1260/1478-0771.9.4.397>.
- Kretzer, Manuel. 2014. "Architecture in the Era of Accelerating Change." In *ACADIA 2014 Design Agency: Proceedings of the 34th Annual Conference of the Association for Computer Aided Design in Architecture*, 463–72. Los Angeles: Riverside Architectural Press.
- Méndez Echenagucia, Tomás, Alfonso Capozzoli, Ylenia Cascone, and Mario Sassone. 2015. "The Early Design Stage of a Building Envelope: Multi-Objective Search through Heating, Cooling and Lighting Energy Performance Analysis." *Applied Energy* 154: 577–91. <https://doi.org/10.1016/j.apenergy.2015.04.090>.
- Oxman, Neri. 2010. "Material-Based Design Computation." Ph.D. Thesis in Massachusetts Institute of Technology.
- Oxman, Rivka. 2012. "Informed Tectonics in Material-Based Design." *Design Studies* 33, no. 5: 427–55. <https://doi.org/10.1016/j.destud.2012.05.005>.
- Vaishnavi, Vijay K., and William Kuechler. 2015. *Design Science Research Methods and Patterns: Innovating Information and Communication Technology*. 2nd. Boca Raton: Crc Press.
- Vazquez, E., B. Gürsoy, and J.P. Duarte. 2020. "Formalizing Shape-Change: Three-Dimensional Printed Shapes and Hygroscopic Material Transformations." *International Journal of Architectural Computing*. 18, no. 1: 67–83. <https://doi.org/10.1177/1478077119895216>.
- Vazquez, E., U. Poerschke, and J.P. Duarte. 2020. "Masonry screen walls: a digital framework for design generation and environmental performance optimization." *Architectural Science Review*. April: 1–13. <https://doi.org/10.1080/00038628.2020.1749552>.
- Vazquez, Elena, and Jose Duarte. 2019. "Computational Tools for Designing Shape- Changing Architectures." *ARCC 2019 The Future of Praxis* 1, no. 1 (June): 118–26.
- Vazquez, Elena, Clive Randall, and José Pinto Duarte. 2019. "Shape-Changing Architectural Skins: A Review on Materials, Design and Fabrication Strategies and Performance Analysis." *Journal of Facade Design and Engineering* 7, no. 2: 91–102.
- Velikov, Kathy, and Geoffrey Thun. 2013. "Responsive Building Envelopes: Characteristics and Evolving Paradigms." In *Design and Construction of High Performance Homes*, edited by F Trubiano, 75–92.
- Yoon, Jungwon. 2019. "SMP Prototype Design and Fabrication for Thermo- Responsive Faade Elements." *Journal of Facade Design and Engineering* 7, no. 1: 41–62. <https://doi.org/10.7480/jfde.2019.1.2662>.

FROM SEGREGATED TO INTEGRATED: The Evolution of Shading Designs in Marcel Breuer's Works

Yuan Yao
Southeast University

Abstract: External sunshades, or brise-soleil in French, have played a significant role in the development of 20th century modern architecture history. An early promoter was Hungarian-American architect Marcel Breuer, who believed sun shading was a crucial architectural design motif. The sunshades in Breuer's early works were elaborately designed and attached to the glass wall façades. After 1960, they were no longer separated devices, but integrated to the new molded concrete façade system. Existing scholarship on Breuer is mainly focused on his furniture and housing designs produced during his early period and his aesthetic interest in the symbolic expression of prefabricated concrete structure. However, the evolution of Breuer's shading designs demonstrates a shift in his attitude from a segregated mode to an integrated one.

The interest of this paper is to review his development of sun shading designs, in order to argue how the concept of integration organizes Breuer's later façades. First, a study of the UNESCO headquarters secretary building demonstrates how a sun-shading design based on performance analysis fails to properly control the overall thermal environment of building. Then, a number of case studies attempt to unfold Breuer's integrated design process and various interrelationships between shading design and other architecture elements like structure, texture, mechanical systems, and architectural programs. The integrity in Breuer's design frees the façade from the modern concept of segregation, which is technically contradicted in nature, and leads to a more effective design process and a more meaningful architectural representation.

Keywords: Sunshade, segregated, integrated, Marcel Breuer

1. THE EMERGENCE OF MODERN SUN SHADES

1.1. SUNSHADES AS A SEGREGATED ARCHITECTURAL COMPONENT

The modern concept of the sunshade, called brise-soleil in French, is first proposed by the Swiss-French architect Le Corbusier. As Reyner Banham suggests, it was a remedy for Le Corbusier's transparent glass membrane, which was unable to exclude the excessive solar radiation (Banham 1969, 158). The emergence of the sunshade, as Aladar and Victor Olgyay point out, was a consequence of the separation of the wall into different elements playing distinctive roles after the rise of new structural possibilities (Olgyay 1957, 6). Compared to the multi-functional traditional walls, the modern ones were explicitly divided into skin (enclosure) and skeleton (structure). The former consisted of large panes of glass to be distinguished from the latter, and meanwhile generated a new spatiality of freedom. The problem of the glass wall was apparent. It introduced enjoyable light and view but also increased the heat load, making the interior inhabitable. At first, Le Corbusier introduced the concepts of la respiration exacte and le mur neutralisant to balance the air circulation, heat exchange and light between the architecture and the environment, manifesting an interior space thermostatically at 18°C all over the world. However, the ineffectiveness brought the sunshade design to the stage.

A segregation between the sunshade and the building structure is noticeable. On the one hand, such a division is submitted to the modern concept of the building system, where each element is treated and represented respectively. On the other hand, the segregation leads to a scientific design method focused on the sunshade individually at the risk of being isolated from the design process.

1.2. SUN SHADING AS A SEGREGATED DESIGN PROCESS

In the book *Solar Control and Shading Devices*, the Olgyays give a broad historical review of shading design. They argue that the correlation of human habitats with natural elements has a long history. The organization of architectural spaces often correspond to the movement of sun and solar control. Indian shelters, Louisiana villa verandas, and Tucuman country house colonnades are listed in the text as evidence (Olgyay 1957, 8).

However, as reviewed above, the modern sunshade is a remedy rather than an intention. Its main task is to effectively regulate heat, closely related to the exterior conditions like air temperature, solar altitude, and sun path, while little related to the inside. With the scientific method the Olgyays developed in the book, the geometrical feature of sunshade

devices is emphasized by and related to shading efficiency. The shading mask was further developed to analyze a sunshade's geometrical parameters with a corresponding diagram, in order to establish direct visual connection with the diagram of a sun path. In such a way, a series of sunshade prototypes are classified and clearly represented by shading masks and section drawings. Case studies in Part 4 of the book are analyzed and displayed in the same way. Relationships with the building structure and interior space are hardly mentioned. As David Leatherbarrow and Richard Wesley observed, "Trimed and sized as they are, these photographs deprive the devices of specific relationships to the climate they modify and the interiors they protect." (Leatherbarrow and Wesley 2014, 174).

2. SUNSHADE DESIGN IN BREUER'S WORKS

Sun and shadow were significant design motifs of the Hungarian-American architect Marcel Breuer throughout his entire career. It informs the title of his first biography edited by Peter Blake (Blake 1956). In this book, Breuer showed his enthusiastic attitude on the wide openness provided by the new glass architecture. Hence, the sunshade was considered one of the basic architectural forms to control the heat and consequently a significant element on the building façade. Breuer even claimed that "[the sunshade] may develop into as characteristic a form as the Doric column" (Blake 1956, 117). The expression of the sunshade also endowed his buildings with a unique character.

2.1. SUNSHADE DESIGN BEFORE 1960

Various forms of sunshades were designed in Breuer's domestic projects during his early career before 1960, as he once claimed, "nearly every one of my works is an experiment in sun protection" (Hyman 2001). For example, canvas awnings were installed in the Doldertal Apartments in Zurich (1934), wooden slats were projected by cables in his own house in New Canaan (1947), and corrugated asbestos panels used in Dwight Ferry Jr. Cooperative house in Vassar College (1949). Breuer concluded two main technical principles in sun shading design: first, the sunshade should be made of slats rather than solid panels in order to let the heat that accumulates outside the window escape more easily. Second, sheets of "solar glass" that absorb heat and reduce glare were introduced as part of the sunshade device (Blake, 119).

Since solar glass would not interrupt the view and could be easily self-cleaned in the rain, it became a standard detail in Breuer's sunshade design after 1950 (Blake 119,123). The glass shade was first realized in the Smith House (1950), fixed by metal clips and cables to lessen its visual appearance, as the house



Figure 1: Wall section on the southeast of Starkey House.

Source: (Syracuse University Library 1954-55)

Figure 2: East view of Starkey House. (Image by Ezra Stoller, from Robert McCarter, Breuer, 2016)

was located in a valley with beautiful scenery. In a later design, the Starkey house (1954-55), the sunshade on the southeast façade was a combination of solar glass and wooden louvers. Both were connected to the roof structure through steel pipes. The wooden louvers were at the same height of the top of sliding windows, providing shade for the area where people gathered near the windows. The solar glass in the upper part, may not have been intended for the view, and was probably set for the light to penetrate deeper into the house, with reduced glare and heat radiation (figures 1-2).

UNESCO headquarters secretary office building 1952-58

The sunshade design in the UNESCO headquarters secretary office building assembled all the characteristics in works of Breuer's prior to 1960. Nevertheless, it also amplified the problems existing in his previous works, to which he had not given enough attention.

The secretary building was designed in the shape of a Y, creating three curved surfaces which had six different oriented façades. Based on the data of the air temperatures and the intensity of direct solar radiation on each orientation, the SE, SSW, and WSW façade required additional sunshades (Howard 1959). As shown in the drawings, the shading system consisted of three layers (figure 3). The first was horizontal concrete louvers of 0.8m wide projecting from the floors, providing a primary shading. The slats were inclined to prevent any incident light and left space for hot air to rise and escape. The second layer was the vertical travertine panels, which mainly blocked light coming from sides and prevented the glare effect. The third was the heat-absorbing glass panes. The glass shade assisted in blocking the light from a relatively low incident angle (Fernandez 2011). The distance between the glass pane and the window was decided according to the orientation of façade, varying at 1.1m, 1.3m and 1.5m. The longer distance meant a better protection for lower angles of sunlight. According to the calculation, the shading efficiency of the whole system on SE façade was about 70% at 11 am, which was proposed as the time when the interior temperature reached its climax,



Figure 3: The sun shade of the Unesco House. (Syracuse University Library 1958)

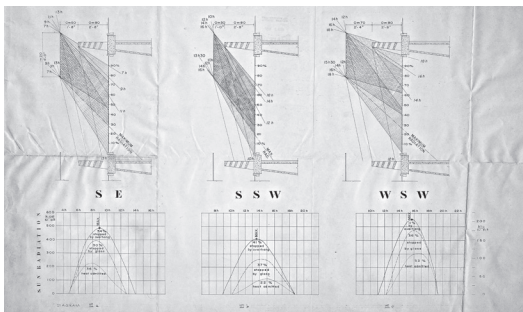


Figure 4: The study of placement of solar glass on three different overheated façade, and the diagram shows the percentage of heat stopped by concrete slats and solar glass. (Syracuse University Library 1955-58)

on August 1st (Fernandez 2011) (figure 4). The shading analysis was taken by the young Polish architect Piotr Kowalski, who had been working for the Olgyays at MIT, before graduation.

However, the real overall thermal performance of the building was far from satisfactory. The occupants complained about the overheating problems right after their first stay, during the summer of 1958. According to the report in 1959, the overheating interior during summer could be attributed to the following reasons: (Rapport sur la protection contre la chaleur des bureau du Palais de l'UNESCO 1959)

1. The inefficiency of the external shading system. The use of full-height glass panel walls was questioned as the lower part was left unprotected

and easily introduced solar radiation during the afternoon. The heat-absorbing glass panel was questioned as well on its ability to block heat and was treated mainly as an anti-glare element.

2. The low thermal inertia of light construction. Partition walls were thin plaster plates glued to honeycomb papers. The ceiling material was very insulating, in order to keep the heat from being absorbed by the underside of the upper floors. Moreover, as Vanessa Fernandez mentions in her research, the concrete slabs were even thinner than traditional ones, further reducing the capacity for heat storage (Fernandez 2011). Hence, the heat was rapidly accumulated inside, leading to higher temperature than outside.
3. Lack of ventilation. Transoms were originally designed, and cross ventilation was factored into the sunshade studies (Howard 1959). Due to costs limits, they were cut out in construction and thus led to severe lack of air movement in actual use.

The final solution ended up by adding wooden blinds outside the window, which was strongly rejected by Breuer himself. Critiques also arose from theorists like Lewis Mumford. He criticized the building for repeating the forms of modern technology, which had been proved inefficient already, and the largest misapplication was the use of an all-glass wall. The sunshades together with the Venetian blinds were neither technically nor esthetically satisfactory and left cleaning problems. As Mumford (1960) suggested, the sunshades in the UNESCO were symbolic rather than functional.

The above reasons illustrate that heat control could not count on the sunshade alone. The failure is a synthetic consequence of the entire building system. Each element is responsible. The lower glass serves little for the spatial openness, while it becomes the main culprit in introducing excessive solar radiation. The thin concrete structure, creatively designed by Nervi, supports effectively but loses the adequate capacity for heat storage.

Modern architecture tends to focus more on each element individually, like the structural efficiency of the framework, the openness of the glass wall, and the effectiveness of the sunshade systems, leading to a segregation of the design elements. Indeed, the sunshade design during the 1940s to 1960s is given excessive attention, and the shading effect is ensured by complicated multiple layers of slabs or louvers, which at the same time provide an expressive outlook. However, the openness that architects had originally aimed for vanished behind the mask of shades. The culture of the brise-soleil leads to a new aesthetic value in which buildings are faceless, covered by veils.

2.2. SUNSHADE INTEGRATED INTO THE MOLDED FACADE

After the failure of the UNESCO building, Breuer did not stick with his concept for an architecture of openness any longer and ceased to treat sunshades as the only element responsible for heat control. He was tired of the separation. Robert F. Gatje, one fundamental partner of Marcel Breuer & Associates, concluded in his memoir of Breuer that modern architecture glorified the separation of structure from envelope and Breuer, following Le Corbusier, had tried out every variation in expressing the separation of structure, systems, and enclosure. But Breuer disliked separation, especially the column, which was freed from the façade but interrupted the inner space (Gatje 2000, 102). He began to reconsider the traditional masonry buildings where mechanical systems and pipes could be accommodated in their massive construction, which was relatively thermostatic. The "balloon frame" of the typical American house also found a renewed appreciation for its capability to house the ducts, wires, insulation, plumbing pipes (Gatje 2000, 102). It is clear that Breuer abandoned the separation concept of modern architecture and was seeking a new construction model, where all the functions which existed in traditional construction remained and within which modern technologies, like radiators and air-conditioners, could be integrated. The sunshade was also transformed from a segregated element to being merged into this new system.

In 1966, Breuer announced his new, prefabricated, thick concrete façade in the article "The Faceted, Molded Façade: Depth, Sun, and Shadow" in *Architectural Record* (Breuer 1966). It was comprised of thick concrete panels with a deep window protected in the strong shadow. In a comparison with the glass wall envelope, Breuer pointed out three major advantages of the new façade in the article: its integration with the periphery column which frees the interior space, its improved protection against sun radiance and climatic fluctuations, and its great accommodation for modern mechanical systems like air-conditioning. The last two points illustrate what Banham (1969) called the structural solution, and the power-operated solution, and both were combined in Breuer's new approach.

IBM Research Center, La Gaude, France, 1960-62

The concrete façade system first appeared in Breuer's competitive design for the tower office of One Charles Center in Baltimore, MD USA in 1960. The study drawings on the exterior wall containing elevation and section, respectively focused on the shading effect and the integration of air-conditioning within the façade structure. The concept of prefabrication was also shown in the dimensioned details. The design was not

approved in the end, but it made a ready preparation for Breuer's following work in the IBM center in France.

The IBM Research center in Le Gaude, France, 1960-62, became the first realized project of Breuer's concrete molded façade (Gatje 2000, 102). The main building is in double-Y-shape with two-story laboratory elevated by tree shape concrete columns. Each unit module was 1.8m wide according to IBM's preference and 1.1m thick to make a column-free interior space (McCarter 2016, 270). The window glass was set 80cm inward from the external face of the vertical fin (figure 5). Drawing measurements indicate that the point of the spandrel and the top of the windowsill form an incident angle of 72 degrees. According to La Gaude's latitude N 43°43'22", the incident angle in the summer solstice is around 70 degrees; such a depth of window would offer adequate shading during summer. The Venetian blind was installed as well behind each window to provide additional protection when needed. The vertical concrete fin and horizontal angled panel provide passage for plumbing pipes. The air conditioning systems and ducts were located below concrete beams covered by suspended ceilings, which was little different from the One Charles Center.

The façade was load-bearing and accommodated pipes systems spontaneously, which meant the grids of force and of pipes overlapped and needed special attention at the joints. It would be apparent from the

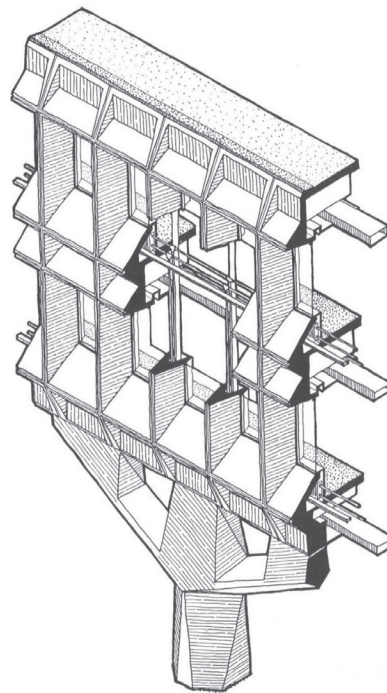


Figure 5: Axonometric of façade system in IBM research center, La Gaude, France, 1960-62. (F. Gatje, R. 2000)

SK drawings that the beams were at first located in the middle of the spandrel to give way to the vertical pipes (figure 6). However, such an arrangement was inconvenient when placing the interior partition walls. In the final construction, the beams were aligned to the vertical fins with a magnified beam head leaving an opening in the joint (figure 7). The façade was not intended to be precast at first. However, with the advice of the contractors, the concrete panels were precast by wooden formworks, which left the same parallel traces as those found on the concrete columns (McCarter 2016, 104).

Comparing the layered façade in the UNESCO building, the one in the IBM project shows a highly integrated design process and a synthetic result, in which every element is closely interrelated and engaged, while the UNESCO is an assembly of different elements that work toward different purposes. The sun shading is no longer an added element designed separately and attached to the façade afterwards. It merges into the envelope system. Moreover, as Tician Papachristou, one of the partners of Breuer, claimed, the precast units are the expression of functional demands (Hyman 2001, 156). The following cases illustrate different considerations relating to the form of Breuer's molded concrete sunshades.

2.2.1. TEXTURE AND WEATHERING

As an external element exposed to natural forces, sunshades confront dirt, water, and other weathering processes. This is a serious problem to Breuer, who claimed that one advantage of glass shading was its self-cleaning ability in the rain (Blake 156, 123), and it was also one of the reasons he strongly rejected external Venetian blinds in the post-occupancy design remedy of the UNESCO building.

Concrete, in Breuer's mind, was a material that aged well in nature (Hyman 2001, 157). In his early concrete practices, he preferred to leave traces of formwork on the surface of concrete, both for the precast and cast-in-place elements, like he did in the IBM center in France. However, Gatje said it did not weather well actually (Hyman 2001, 156). In the later projects, the prefabricated panels were usually sandblasted with acid washing to make a rough surface with slightly exposed aggregates. The rough texture has another function for shading efficiency and lighting condition, as it reduces the reflection of visible light into the interior space intensifying overheating and glare. Although it might have been a choice based merely on the aesthetic decision by Breuer, it coincided with good environmental performance, as other environmentalists, Baruch Givoni for example, researched during the 1960s.

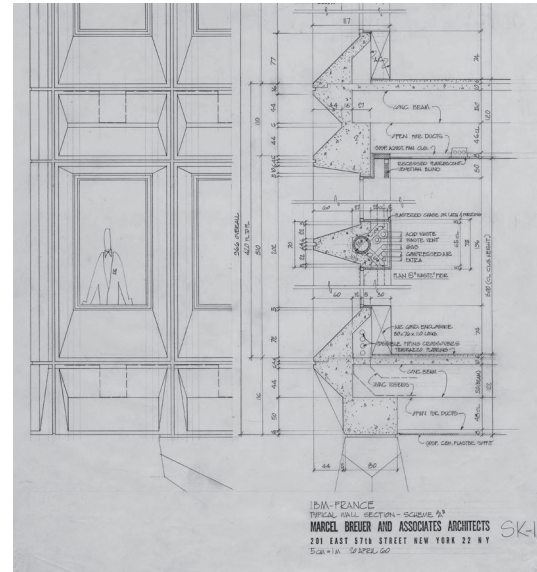


Figure 6: Exterior wall elevation and section, IBM Research Center, La Gaudie, France, 1960-04-20. The outline of the beam on the elevation showed the beam's original location. (Syracuse University Library 1960)

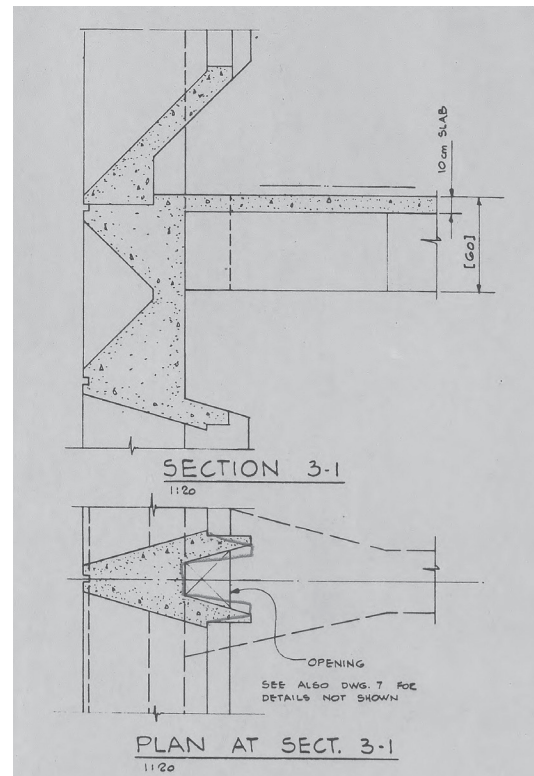


Figure 7: Joints of the beams and spandrels, IBM Research Center, La Gaudie, France, 1960-07-18. The head of beam was thickened to leave openings for pipework. (Syracuse University Library 1960)

Scoring lines are also important to keep the concrete and even the window clean, as the two are connected in the molded concrete façade system. The detail was omitted in Breuer's IBM center in France, which was probably a reason for the bad weathering. The scoring line appeared in the Department of Housing and Urban Development (HUD) in Washington D.C. USA, 1965-68, however, the scoring line was right next to window and seemed like a final remedy which was not shown in the original constructional drawing. In the later project, scoring lines were usually located next to the outer edge of the bottom side of the sunshades, such as at the Armstrong Rubber Company in New Haven, CT USA, 1968-70 (figure 8).

2.2.2. STRUCTURE

As Breuer's façade is usually load-bearing, the form of the facade is closely involved with the entire structural system, and therefore leads to different shading patterns. In most cases, like the IBM research center in La Gaude, the façade is a thick grid with windows deeply folded inward. This appearance relates to the structural logic that each panel is one floor high and transfers the load from the upper floors. However, in a few cases, the sunshade is formed by vertical and horizontal fins projecting outward rather than the opening placed inward. Structural logic, instead of a pure aesthetic choice, lies behind the change of shading.

An example is the façade of the IBM laboratory building in Boca Raton, Florida (1968-72). Like the project in La Gaude, it was a three-story building, with the upper two stories elevated by concrete tree columns. With the advanced prefabrication industry in Florida, the structural engineer suggested that the two elevated stories be covered and supported by one single panel (Gatje 2000, 180). T-shape prefabricated beams cover the entire span between the facing facades to create a column-free interior space. Each concrete panel is 2.4m wide and 10m tall and the concrete beam is connected to the middle of the rear side of the panel (McCarter 2016, 388). This structural joint leads to an eccentric force, which creates an additional torsion to the façade structure, and thus a 1.5m deep vertical rib was added on the outside as a stiffener. The rib was centered on each panel, aligned with the T-shape beam supported behind and tapering to the top and bottom, which indicates the bending moment on the façade. Horizontal slabs are added, forming egg-crate sun shadings while the space between the slabs also helped the hot air to escape (figures 9-10).

Similar structure solutions in Breuer's works could be classified into two categories. The first is the large factory building, where the rib is essential for stabilizing the tall exterior wall, such as at the Torin factory in



Figure 8: Exterior view of the sandblasted concrete façade with scoring next to the outer edge. Armstrong Rubber company building, 1968-70. (Ben Schnall, Syracuse University Library 1965-1969)

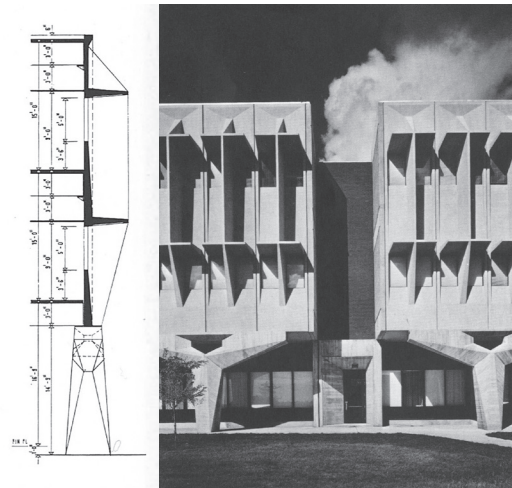


Figure 9: The exterior wall section, IBM administrative office, Boca Raton, FL USA. Source: (Process: Architecture 32, 1982)

Figure 10: View of the façade, IBM administrative office, Boca Raton, FL USA. Process: Architecture 32, 1982)

Nivelles, Belgium (1963). The second is the multiple-story building, where each panel covers more than one floor. The torsion arising from the connections behind the panel make a vertical rib necessary, such as at the Strom Thurmond Federal Office Building in Columbia, SC (1975-82), where vertical ribs and horizontal shades were shown on the facades (figure 11).

Robert McCarter commented on the IBM Boca Raton that:

Even though the sun shades are only partially effective...yet the fact that the precast wall panels are building envelope, window frame, and vertical structure, in addition to sunshades for the windows, and the parallel fact that none of these functions can be removed without diminishing the effectiveness of the others, together assure both the constructional integrity and formal consistency of expression of the building. (McCarter 2016, 388)

Different choice of structure does not sacrifice the existence of sunshades, but instead results in a new expression with structural logic, representation, aesthetic value, and environment performance. This avoids a technology-determined result and instead presents an interesting tension between structural and environmental devices.

2.2.3. ARCHITECTURAL PROGRAMS

As an environmental mediator, Breuer's sunshade varies to create different relationships between exterior and interior, according to the related architectural program. The position of windows and ratio of the void to solid creates different degrees of openness, indicating hidden functions and activities. For office and factory buildings, the façade shading pattern is usually identical and repetitive. When it comes to a multi-function complex, shading variations are created to correspond to the specific programs.

The project for the Campus Center at the University of Massachusetts in 1965-1970 is an explicit example. The project consisted of a large, elevated plaza containing rooms and auditoriums, which did not require natural light, and a nine-story block standing on it. The block was a multifunction complex with the mechanic rooms on the ground floor, campus hotel from the second to the fifth floors, office section on the sixth and seventh floors, and restaurants on the top two. An additional penthouse for machines lies on the roof (figure 12).

The varying shading patterns on the south façade illustrated a closed relationship with the programs inside. The panel for the hotel section is thirteen feet wide each, corresponding to one ordinary suite. Based on a higher level of privacy, there was only one opening of five foot square on one side of each panel, which faced directly to the entrance of the suite. The bathroom and sleeping area were enclosed by the solid section. The office section was covered by a concrete panel of the same width, but further divided by an additional mullion in the middle to create a pair of windows. The taller openings introduce more light for office working inside. The top restaurant became even more open without being enclosed by the molded concrete panels. The whole two-story volume was stretching outwards, containing a 3'6" wide balcony on each floor protected by precast-concrete grilles. The separation between balcony and restaurant was a full height glass wall with sliding doors, providing maximum visibility to the view outside (figure 13).

This campus center represented different characteristics from the UNESCO office. In the latter, an extreme degree of openness was expected with a severe sacrifice of climatic management, while the UMass center exhibited a much more flexible approach to façade design, which highly integrated sun protection, view, light, privacy and resulted in a diverse architectural expression.

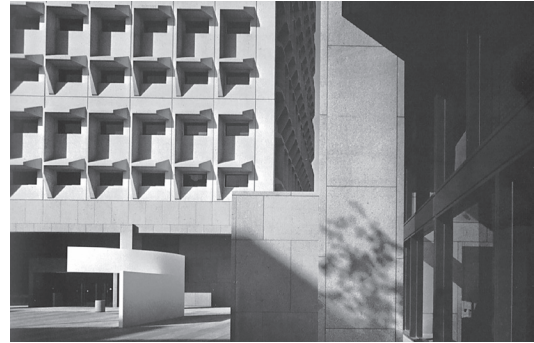


Figure 11: The east view of Strom Thurmond Federal Office building in Columbia, SC USA, 1975-82, most vertical ribs cover double stories and some triple. (Herbert Beckhard 1991)

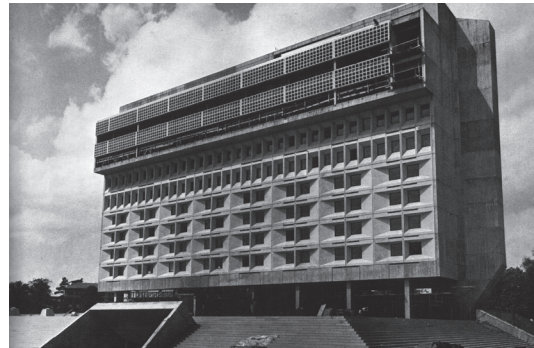


Figure 12: The south façade of the campus center in the University of Massachusetts, Amherst, MA USA 1965-70. (Neil Doherty, Tician Papachristou, 1970)

2.2.4. EQUIPMENT

A unique feature of Breuer's sunshade design, as compared to others during the 1960-70s, is its active integration with modern mechanical devices. Taking air-conditioning as an example, Banham pointed out that the architectural design had a very close relationship with the air-conditioning system at the beginning, however, as air conditioning developed to a simple box which could be easily installed anywhere, its relationship with the structure had vanished and meanwhile brought about conflicts with the façades (Banham 1969, 187-91). The Kips Bay Apartments by I.M.Pei was a typical negative example illustrated in Banham's book. In Breuer's work, the depth and thickness of the façade was fully exploited to integrate mechanical equipment like air conditioning units.

The campus center in the University of Massachusetts, mentioned in the last paragraph, is a typical example. The air conditioning systems were installed in each unit, under the window of both the hotel and the office, and the narrow horizontal slot clearly indicates the machine behind (figure 14). The detail enriches the façade shading patterns and moreover

From Segregated to Integrated

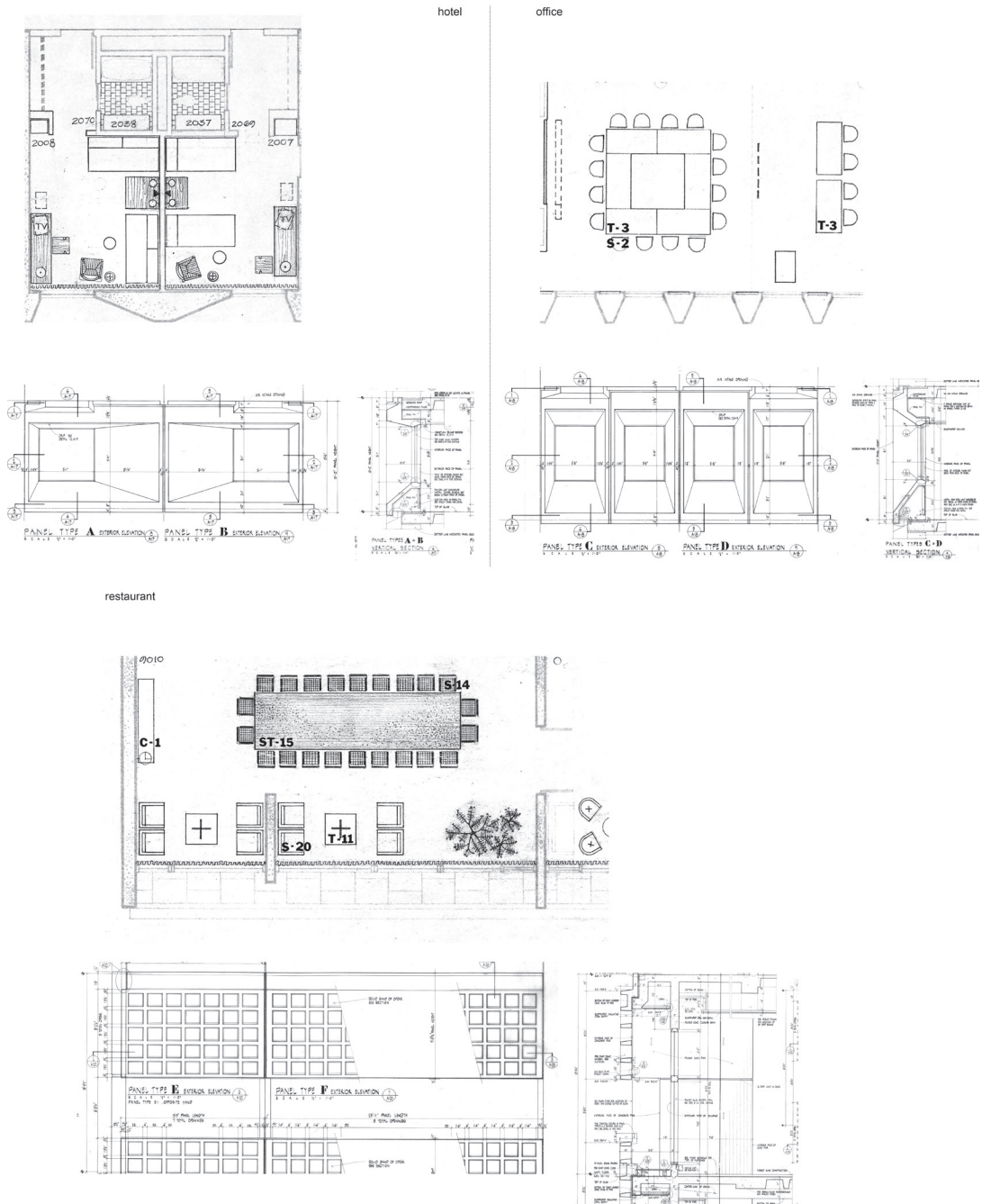


Figure 13: A comparison of plan, elevation, and section of the hotel, office and restaurant, Center Campus of UMass, Amherst, MA USA 1965-70. (Syracuse University Library 1969)

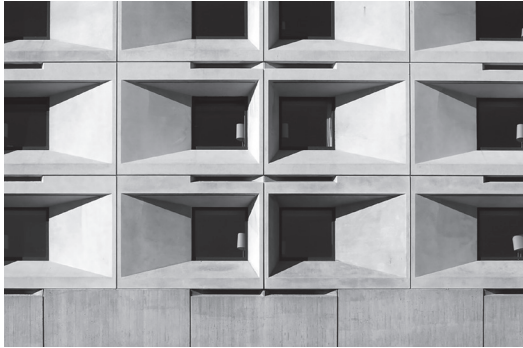


Figure 14: Exterior view of the façade. Campus Center of the University of Massachusetts, Amherst, MA USA, 1965-70. (Bruce M Coleman 2011)

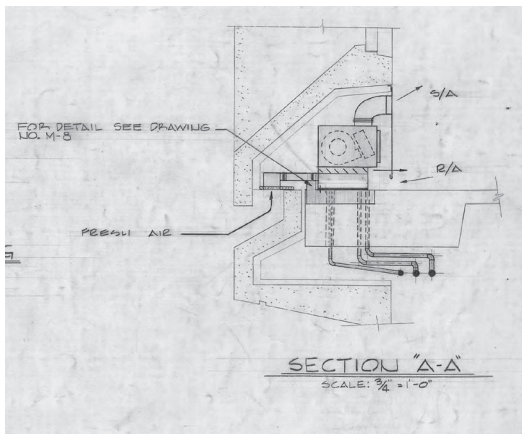


Figure 15: The façade detail of hotel section. The Campus Center of the University of Massachusetts, Amherst, MA USA, 1965-70. (Syracuse University Library 1967)

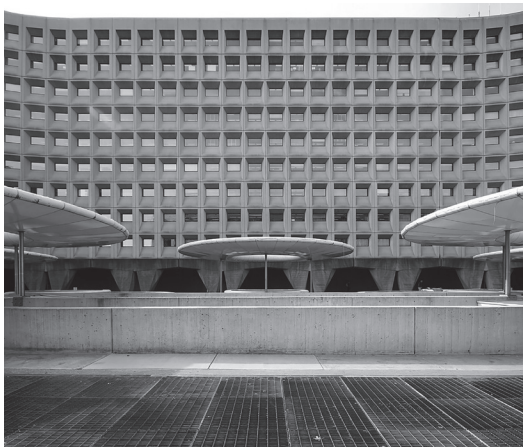


Figure 16: The west façade, HUD, Washington D.C. USA, 1965-68. (Patt Trevor 2018)

shows a close collaboration between the architectural design and engineering requirements. As Robert F. Gatje mentioned, Breuer was careful to coordinate between the architectural drawings and mechanical demands, to ensure the whole façade system was practical technically and aesthetically (Gatje 2000, 130) (figure 15).

The equipment logic expressed on the façade could also be found in the project for the Headquarters of the Department of Housing and Urban Development (HUD) in Washington D.C. USA, 1956-68. The façade was Breuer's typical molded concrete grid, integrating shading and plumbing pipes. The ten story building, with nine of them elevated from the ground, was fed fresh air from both the top and ground level, the vertical columns of the middle four floors were designed thinner than the bottom three and upper two, according to the dimension of ducts. This subtle variation gave the façade a more dynamic expression in its veiled exhibition of the mechanical system (figure 16).

CONCLUSION

Alan Colquhoun summarized that "The brise-soleil was more than a technical device, it introduced a new architectural element in the form of a thick, permeable wall..." (Colquhoun 1989, 187). The care for sun protection, and climatic resistance leads Breuer to his molded concrete façade. Nevertheless, Breuer went a step further to integrate modern mechanical devices and pipes in his envelope system and showed a close relationship with other fundamental architectural elements. He also exemplified a combination of Banham's structural and power-operated solutions, which was unfortunately missed in Banham's texts.

A high integrity of design result is always backed up by a highly integrated working process. Architectural, interior and mechanical design run parallel in Breuer's work, in order to create a building like the UMass campus center, where the program, façade, and mechanical systems are all coordinated in a simple architectural expression. It predicts the future of an integrated cross-disciplinary design approach, which prevails nowadays.

Although there are still a number of projects showing Breuer's pure aesthetic interest in various forms in sun and shadow, the projects shown in this research should not be overlooked and the integrated thinking and details still inspire in today's architecture design.

ACKNOWLEDGEMENTS

This paper owes great help and instruction from Prof. Franca Trubiano, Stuart Weitzman School of Design, University of Pennsylvania and from the detailed original sources collected by Marcel Breuer Digital Archive from Syracuse University Libraries. This research is also financially supported by China Scholarship Council (CSC).

REFERENCES

- Banham, R. 1969. *The Architecture of Well-Tempered Environment*. London: The Architectural Press; Chicago: The University of Chicago Press.
- Olgyay, A. and V. Olgyay. 1957. *Solar Control and Shading Devices*. Princeton: Princeton University Press.
- Leatherbarrow, D. and R. Wesley. 2014. "Performance and Style in the Work of Olgyay and Olgyay." *Architectural Research Quarterly* 18, no. 2: 167-176.
- Blake, P. 1956. *Marcel Breuer: Sun and Shadow, the Philosophy of the Architect*. New York: Dodd, Mead & Company.
- Hyman, I. 2001. *Marcel Breuer, Architect: The Career and the Buildings*. New York: Harry N. Abrams.
- Howard, S. 1959. "Design of Sunshade for UNESCO." *Architectural Record* 3 (March): 226-229.
- Fernandez, V. 2011. "Preservation of Modern-era Office Buildings and Their Environmental Controls." *The Journal of Preservation Technology* 42, no. 2/3: 21-6.
- Rapport sur la Protection Contre la Chaleur des Bureau du Palais de l'UNESCO*, AAA Unesco file folder. Box12, Reel 5723, Frames 252-341: Chronological correspondence, Jan-April 1959. <https://www.aaa.si.edu/collections/marcel-breuer-papers-5596/subseries-8-3-6/reel-5723-frames-252-341>
- Mumford, L. 1963. "UNESCO House: Out, Dammed Cliché!" In *The Highway and the City*, 67-78. New York: Harcourt, Brace & World.
- Gatje, R.F. 2000. *Marcel Breuer: A Memoir*. New York: Monacelli Press.
- Breuer, M. 1966. "The Faceted, Molded Façade: Depth, Sun and Shadow." *Architectural Record* 4 (April): 171-172.
- McCarter, R. 2016. *Breuer*. New York: Phaidon Press.
- Colquhoun, A. 1989. *Modernity and the Classical Tradition: Architectural Essays, 1980-1987*. Cambridge: MIT Press.



Georgia Institute of Technology
School of Architecture
245 4th Street, NW, Suite 351
Atlanta, GA 30332

Divergence in Architectural Research

The research that follows does not seek to define divergence; in fact, it is easier to say what it is not than what it is. For example, divergence is not synonymous with inter-disciplinarity, which emphasizes a sharing across established boundaries. Inter-disciplinarity seeks resemblances and shared methods and motivations, ignoring all the rest. The search for sameness usually remains on the surface; it is unsustainable over a long-term and ultimately not very effective for investigating the breadth and depth of a discipline. Rather, from within architecture, the projects that follow choose to explore subjects, techniques, and methodologies that diverge, sometimes intentionally, sometimes organically, from the canon of research in architecture. In doing so, they expand the field of exploration and also point to how this canon, once privileged as a means of ordering and defining a distinct cultural and professional identity, may also have inadvertently reduced the subject's active, living quality—architecture's agency. These essays take architecture's agency as primordial, with its variations, energies, and movements, and allow it to shape the course of their research program, their conclusions, and their speculations for the future of research in architecture.

